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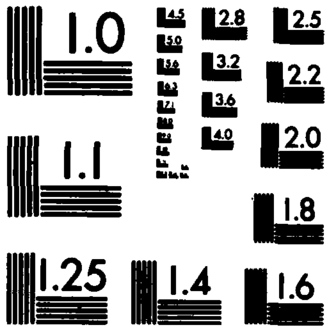

MICROCOPY RESOLUTION TEST CHART
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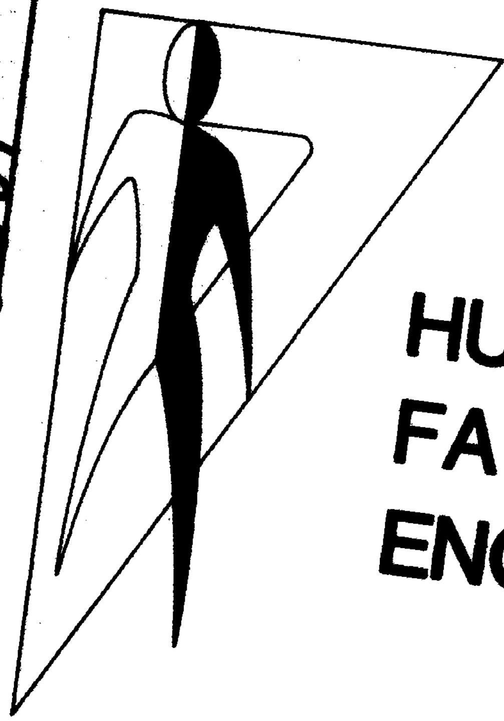

HUMAN FACTORS ENGINEERING

A Self-Paced Text
Lessons 16-20

Approved for Public Release:
Distribution Unlimited

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US ARMY HUMAN ENGINEERING LABORATORY
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HUMAN FACTORS ENGINEERING

LESSON 16: VIGILANCE, OR STAY AWAKE IF YOU CAN

So, 15 lessons under your belt and still eagerly plugging away. Good for you!

In the last several lessons, you studied about some of the physiological problems or limitations that affect human performance. Can you remember what types of process those lessons dealt with?

(1) Sensitivity to motion. Turn to Page 62.
(2) Both of these concepts were dealt with in the last several lessons. Turn to Page 41.
(3) The kinesthetic senses. Turn to Page 50.

- -

From Page 21

(2) One factor that affects performance is humidity, but this isn't the best answer to this question. Return to Page 21.

- -

From Page 9

Similarly, when the noise is irrelevant (not providing any needed information) to the job, high frequency noises tend to be associated with more errors in performance than do lower frequency noises. Also, higher frequencies tend to create faster response times by the individual to any reaction time tasks than do lower frequency tones. It has been suggested that both of these effects of frequency can be explained on the basis of the greater attention-arousing quality of higher frequencies. Do you think this could be so:

(1) To date, no one has been able to explain adequately this phenomenon. Turn to Page 49.
(2) Yes, high frequencies enhance performance when the sound is a relevant signal, but are distracting when the sound is irrelevant. Turn to Page 48.
(3) These findings have only been reported in studies of questionable design, and, therefore, should not be considered accurate. Turn to Page 63.
(4) No. It has been shown that, in general, lower frequency tones are more attention arousing. Turn to Page 13.

- -

From Page 78

(4) Very good. Pressurized cabins are used to prevent or reduce hypoxia. Pressurized cabins are required in all high-altitude civilian planes and in some military aircraft, and, as a result, no oxygen masks are needed.

If, for some unfortunate reason, the pressurization in the aircraft were to be lost suddenly, the use of oxygen masks becomes imperative if the occupants of the craft are to remain conscious. The time during which the individual is able to perform purposefully after being exposed to an hypoxic condition is called the time of useful consciousness. It is during this time that the person (say the pilot), must determine the cause of the condition and take an appropriate action to protect himself and those on board, if possible.

Without any oxygen in his body, the individual will be dead within 90 to 180 second. Therefore, it is extremely important to utilize the time to useful consciousness to its fullest.

Now, you may be wondering what this has to do with you, the human factors specialist. Well, if you keep in mind that your primary concerns are the task requirments and the human capabilities to perform them, we think you'll understand. In the present example, the task requires that oxygen equipment be donned in an extremely short period of time. You know that the longer the person goes without oxygen, the more he becomes dysfunctional. Your part of the job, therefore, should be to ensure that oxygen equipment is available within a few seconds and that it doesn't require much effort to put it on. You're probably aware that pilots who fly at high altitudes are required to wear oxygen masks to protect themselves against the possibilities of an hypoxic condition. If you'll remember our earlier discussion of pressurized cabins, you're aware of the pressurized cabin requirement. However, when high altitudes are reached (i.e., around 18,000 feet) the pressurized cabin is often not sufficient to counteract all side effects of the high altitude, and a slowing of reaction time may begin to occur.

Figure 18.2 in your supplement shows the time required to don oxygen masks for a group of trained pilots and a group of naive subjects. How many seconds did it take for all of the trained pilots to put on their masks?

(1) About 30 seconds. Turn to Page 8.
(2) About 20 seconds. Turn to Page 12.
(3) About 40 seconds. Turn to Page 39.

From Page 73

(2) Soft noise is not an intense distraction, and continuous presentation does not distract from performance as much as intermittent noise does. Return to Page 73.

From Page 7

(4) Performance declines much more at a particular period of watch. Return to Page 7.

From Page 44

(2) We tricked you! Noise levels aren't recorded in degrees, nor is temperature recorded in decibels. Get with it! Return to Page 44.

From Page 80

(2) Nope, wrong answer. Return to Page 80.

From Page 8

(2) Right, this gas is a particularly deadly one and is also hard to detect.

The reason carbon monoxide is so toxic is that it has a great affinity for blood hemoglobin. Controversy exists in the scientific community relative to the percentage of CO in the blood which will degrade human performance. However, the basis for the present military standards governing human exposure to CO is that established for the industrial community and only addresses issues of health and safety. These standards are based upon the individual being exposed while exerting little physical effort for a typical 8-hour working day and can be found in MIL-HDBK-759. It is suggested in US Army Human Engineering Laboratory Technical Memoranda 11-77 and 1-80 that these standards are unrealistic for a wartime situation. In warfare, high exposures for short, intense durations as well as steady-state exposure, will often occur. A long duration, fairly constant concentration of CO can be provided by a moving or stationary vehicle with the engine running. For example, constant level exposure is typical of the expected in a truck, enclosed vehicle, helicopter, aircraft cockpit enclosure, or even by a troop squad using a moving vehicle for protective cover. On the other hand, brief, high-level concentration results from firing weapons from an operating vehicle, be they machine guns, automatic rifles, or artillery pieces. It is recommended in these documents that long-term regular exposure not exceed 5 percent on the average. For the military population, because of being in top physical condition, the occasional level of 10 percent will not constitute a health hazard, but levels of CO 10 percent or above may compromise human performance.

Okay, in your last lesson you learned that people can get accustomed to the effects of severe cold and heat. Do you think that it is possible to become adapted to the effects of CO?

(1) Yes. Turn to Page 13.
(2) No. Turn to Page 22.
(3) Undecided. Turn to Page 30.

From Page 21

(3) Workload is one factor that affects performance, but how would prior performance decrements affect current performance in heat? Return to Page 21.

From Page 51

(2) Increasing the intensity of the signal does increase the chances of detectability. You're absolutely right.

The probability of detection is positively related to signal intensity. There should be minimal difficulty in maintaining vigilance if the signal is well above threshold levels. Thus, wherever possible, it is best to keep the signal somewhat above threshold values in order to increase detectability.

Let's talk about one additional signal characteristic that affects vigilance, namely, rate of signal presentation. In terms of this variable, it has been generally concluded that the probability of signal detection tends to increase as the signal rate is increased. Thus, for example, if you were contemplating the use of one of four signal rates (25, 50, 75, or 100 signals per hour), the presentation of 100 signals per hour would result in the highest detection percentage.

Now that you've been introduced to signal characteristic variables that affect vigilance, try this question. Taking into account what has been said so far about signal characteristics, which of the following signals would you employ to increase signal detectability?

(1) A dim light presented 25 times per hour and remaining lit for 2 seconds at each presentation. Turn to Page 88.
(2) A bright light presented 5 times an hours and remaining lit each presentation for approximately 2 seconds. Turn to Page 99.
(3) A bright light presented 25 times an hour and remaining lit each presentation for approximately 2 seconds. Turn to Page 43.
(4) A dim light presented 25 times an hour and remaining lit for approximately 1 second at each presentation. Turn to Page 92.

From Page 84

(1) While it's true that man is somewhat limited in terms of his processing capabilities, this answer places too much emphasis on the machine. Return to Page 84.

From Page 21

(1) Sure, all of these things affect performance in heat.

As workload increases, man's ability to perform decreases. If you further add the stress of extreme heat, his performance level again decreases. Fluid loss, if excessive, may lead to dehydration, which must be avoided, because it can lead to serious physiological consequences.

Now, which of the following tasks would you expect to be most affected by heat?

(1) Walking five miles. Turn to Page 12.
(2) Riding a bike 10 miles. Turn to Page 86.
(3) Mining for gold. Turn to Page 49.

From Page 8

(1) Sorry, you've already learned about carbon dioxide. Return to Page 8.

From Page 99

(3) A vapor pressure of 15 mm HG is about the lowest level contained within the summer comfort zone. By looking at the lower 'bracketed' end of the summer comfort zone, and then following that line down to the bottom of the graph (labeled 'vapor pressure'), you'll see that it intersects the 15 mm HG vapor pressure point. Return to Page 99.

From Page 42

(4) Well done. It's obvious you understand where we are and what we're discussing at the present time.

So, vigilance or watch-keeping behavior deals with the ability of the operator to stay alert and detect the appearance of infrequent signals. Now that we've clarified that, let's continue with our general introduction to this important topic.

Many tasks call for prolonged watchfulness with only an occasional response. A good example of this type of vigilance is the production-line worker who must inspect similar articles as they move by on the conveyor belt. He must stay attentive and remain vigilant in order to pick out an incomplete, irregular, or misassembled item. Drivers on a busy freeway and pilots scanning instrument panels are also good examples of personnel involved in watch-keeping activities. In both of these last two instances, much more frequent responses are usually required.

With the passage of time, almost any repetitive task we are exposed to becomes dull and boring. With an increase in boredom, we also find an increase in number of errors (both missed and incorrectly identified signals). As we stated earlier, interest in vigilance increased greatly around the time of the Second World War. In large part, attention was focused on this area when it was realized that personnel involved in monitoring enemy vessels tended to report far fewer vessels than were known to be in a particular area. Since then, it has been found that the probability of signal detection declines as time on watch progresses; this decline reaches its maximum within the first hour on watch. After the first hour, performance decrement is much more gradual the rest of the period. Some studies have also shown a slight improvement or recovery near the end of the watch, when operators were aware of the duration of the watch.

Okay, see if you can answer the following question based on the preceding discussion. During a 2-hour watch, when would vigilance show the greatest performance decrement?

(1) Probably the greatest performance decrement occurs during the first 30-60 minutes of the watch. Turn to Page 51.

(2) The poorest watch-keeping performance is found in the last 30 minutes of duty. Turn to Page 94.

(3) There is no difference in vigilance over an entire watch period. Turn to Page 100.

(4) Poorest watch-keeping performance occurs at the beginning and end of the watch period, with relatively stable performance in between. Turn to Page 3.

From Page 2

(1) Very good, you are exactly right. Keep up the good work.

One other aspect to be learned from this figure is that not all naive subjects were able to get their masks on, even after a full minute had passed. This should indicate to you that training improves performance. However, since passengers also suffer from hypoxia and usually aren't trained, it would be better to build into the design a way to reduce the time and difficulty of donning masks.

Okay, enough on oxygen, let's look at some other gases, such as carbon dioxide (CO_2), which affect man. If man is exposed to moderate amounts of CO_2 he might experience such effects as small hearing losses and doubling of respiration rate. If the exposure is extreme, the effects might include such things as mental depression, headache, dizziness, nausea, reduced visual discrimination, and finally, unconsciousness.

On the other side of the coin, when too much CO_2 leaves the body too rapidly, hyperventilation occurs. A number of studies have shown that psychomotor performance is impaired by moderate hyperventilation. Severe hyperventilation has been thought to have caused several aircraft accidents.

One of the aspects of CO_2 is that during high-G maneuvers small segments of the lungs will act like pockets and trap the gas. This, in turn, might cause that portion of the lung to collapse, producing chest pain and coughing. It is important for you to know that this lung collapse can be prevented by ensuring that an inert gas is added to the breathing mixture. Thus, while the presence of this inert gas will not reduce the other effects of CO_2 mentioned above (i.e., headache, dizziness, nausea), it will eliminate the chest pains and coughing.

Now, one of the particularly dangerous gases is odorless, colorless, usually can't be readily detected by the human senses, and has a particularly toxic effect. Can you tell us which of the following gases we are referring to?

(1) Carbon dioxide. Turn to Page 6.
(2) Carbon monoxide. Turn to Page 4.
(3) Ammonia. Turn to Page 31.

From Page 58

(4) Good show, you're absolutely right. Sound waves are converted in the middle ear to mechanical energy, which is then transmitted to the auditory nerve and converted to electrical energy.

Thus, we have shown that the subject of hearing covers the sum total of the transmission of sound from the external environment to the brain. It involves the conversion of mechanical impulses to neural impulses, the transmission of these impulses to the brain, and their 'perception' by the brain. In Lesson 10 on auditory displays, a short presentation was given on properties of sound, but it will be a good review (and this is an appropriate point to discuss it once again, because of our discussion of noise that is to follow). Remember that the sensation of airborne sound is produced when vibrations of the molecules of air strike the ear drum.

When describing an auditory stimulus, one must specify the frequency of the sound and its intensity. In dealing with pure tone, frequency is expressed as 'cycles per second' (CPS) or 'Hertz' (Hz). On the other hand, intensity of a sound wave is a function of the amplitude of the wave and is measured in pressure units. Two terms are widely used in referring to intensity; decibels (dB) and perceived noise (pndB). The decibel is based on the ratio of the sound being measured to a standard sound reference (the standard being the minimum intensity necessary to just detect the presence of a 1,000 Hz tone). The perceived noise (pndB) is a calculated unit used to express unacceptable sound (i.e., noise). This unit is calculated by combining actual sound level with a weighted annoyance factor. This measure of perceived noise has been found useful as a predictor of what actions people annoyed by noise take--ranging from complaints to authorities, to legal action (as has happened in numerous airport 'noise pollution' cases). PndB can be predicted ahead of time from the intensity level of the various frequency components of the noise, and the duration of the noise. To refresh your memory on the dB levels of various everyday sounds, glance back at Table 10.1 in your supplement. This chart should also help in giving you a clearer picture of various dB levels when we discuss how noise affects performance.

In the past, research findings concerning noise and its effects on performance have given rise to confusing and contradictory findings on the subject. This has been due, in large part, to lack of concern with the dimensions of noise. For instance, noises differ in intensity, frequency, and complexity, and might be presented continuously or intermittently. In general, all of these characteristics affect how noise is received and interpreted. Loud noises might have an adverse effect on performance, while less intense noise typically does less harm, or might even facilitate the performance of a given task.

(Turn to Page 1)

From Page 73

(3) You're right, intense noise that is presented periodically is most distracting for performance.

Okay, so far you've covered some of the important physical aspects of noise, and how they affect performance. Now, let's get more specific and deal with several ways this type of information is utilized by the military.

In many military situations, it is important to know the limits of noise detectability and nondetectability. This information is part of MIL-STD-1474B, which presents a general overview of noise limits for Army materiel. Table 3 on Page 24 depicts the upper limits that should not be exceeded by those items of equipment having an aural nondetectability requirement. Thus, for instance, if you wanted to be sure a particualr piece of equipment you were designing could not be heard by anyone standing more than 30 meters away, its noise output could not exceed 43 dB at 500 Hz. We hope you see how this figure is derived. To make sure you understand how to move through this table, let's go through it step-by-step.

Suppose you were required as the Chief, Human Factors Engineer, to design a supply truck that could not be heard 100 meters away. You have information that the engine hum falls in the range of 1000-200 Hz. Now, your task would be to muffle the loudness of the engine so that it does not exceed the critical intensity and be heard at 100 meters.

Okay, by looking at the table, if a 1000-2000 Hz noise needs to be made inaudible at or above 100 meters, you need to move down the 'nominal nondetectability distance' column until you reach 100 meters. Then move across until you reach 2K (or 2000 Hz). This decibel limit is higher than the 1000 Hz noise level, so you adopt this level if you do not want your truck to be heard by anyone 100 meters away.

This same principle can be applied to determine how loud a sound must be in order to be heard from a particular distance. Still using Table 3, you can discover how loud an alarm must be (around 8000 Hz) in order to be heard 500 meters away. With this information, what would the correct answer be?

(1) The alarm must be 49 dB to be heard 500 meters away. Turn to Page 37.
(2) The alarm must be at least 67 dB to be heard 500 meters away. Turn to Page 32.
(3) From the information given, a definite answer cannot be obtained. Turn to Page 82.
(4) None of these answers are correct. Turn to Pag 87.

From Page 44

(3) The ranges given for both noise and temperature reflect values that tend to increase watch-keeping behavior rather than detract from it. It might be good to go back and reread this section on environmental variables that affect vigilance. Return to Page 44.

From Page 78

(2) This answer covers most of the ways to prevent hypoxia, but oxygen masks are not used if the cabin is sufficiently pressurized. Return to Page 78.

From Page 70

(3) These figures are off too far to the left of the graph. Return to Page 70.

From Page 2

(2) Only 95 percent of the pilots had put their masks on by this time. Sorry, but this isn't correct. Return to Page 2.

From Page 58

(2) Good try, but you're not exactly right. While electrical energy is utilized once the signal reaches the auditory nerve, bone conduction is not really another type of energy system. Instead, bone conduction is part of the mechanical conduction process. Return to Page 58.

From Page 71

(1) You've got them backwards. Return to Page 71.

From Page 6

(1) This answer is an example of a physical task, but those tasks that require the greatest amount of exertion are the ones most affected by heat stress. Return to Page 6.

- -

From Page 4

(1) Well, this is the answer. It is believed that a slow build-up of CO, as would occur in a spacecraft, for example, should permit normal functioning. The people in the craft would, over a period of time, increase their hemoglobin and red blood cell supply to be able to tolerate the CO increase. (This is, of course, taking into account the fact that the CO increase must not be too extreme, but within certain limits.)

No matter which type of fuel is used, its by-products include carbon monoxide and carbon dioxide. The permissible exposure times allowed for various concentration of carbon monoxide can be found in Title 29, Code of Federal Regulation, Department of Labor, Part 1910 of the Occupational Safety and Health Administration Standards.

The usual limit of CO is 50 parts per million (ppm) for an 8-hour period. However, this can be increased for shorter durations. For tank design, MIL-HDBK-759 considers amounts of 500 ppm acceptable if the duration is 10 minutes. Why is such an increase permissible?

(1) The Labor Department's limits are outdated and provide too little protection. Turn to Pag 22.
(2) The people in question are young healthy servicemen. Turn to Page 19.
(3) Neither alternative is correct. Turn to Page 36.

- -

From Page 1

(4) Lower frequency tones are not more attention arousing than tones of higher frequency. Return to Page 1.

- -

From Page 75

(3) This was a hard question, but you came through.

Once you know the differences in performance between to two types of environments, you can test new types of equipment to see if they increase or decrease performance over the old condition. You will also have gathered valuable data to use in establishing a training program for the operators.

Well, what can we say? This lesson has been full of information. As always, the more you learn about man's capabilities and limitations, the more you can use that information in designing for man's use.

So now, away from the serious into the sublime. Let's see if I. M. Eager ever got out of the frozen tundra. If you recall, at the beginning of this lesson Eager was telling his fellows about his perfect helicopter. He also was not telling them about his many failures. Much to Eager's chagrin, one of the men present in the audience was an employee of the Basic Air Rework Facility (B.A.R.F.). He knew what Eager had gone through to get a perfect chopper. Being a nice guy, full of charity, he said nothing.

Eager was extremely grateful for this closed-mouth ally and asked if he would like to accompany him back to the home base. The analyst jumped at the chance.

Finally, to a chorus of loud cheers, Eager lifted the perfect helicopter off the ground and started the trip home. Well, wasn't that a nice way to end this segment? We'll see you again in the next lesson. Since that lesson is about noise, we hope you have a quiet break between now and then. So long. Turn to Page 56 to begin Lesson 19.

From Page 73

(1) While intermittent noise does distract more from performance than does continuous noise, this answer does not result in the greatest performance decrement. Return to Page 73.

From Page 92

(1) You are incorrect. There are laws that protect workers from ever-noisy environments. Return to Page 92.

From Page 27

(3) Take a closer look at these areas. We didn't discuss them all. Return to Page 27.

From Page 71

(3) Are you kidding us? We wouldn't have two different dimensions just for fun. Return to Page 71.

From Page 75

(2) This kind of test would not necessarily tell absolute amounts of work performed or tell more about one condition than the other. Return to Page 75.

From Page 42

(3) You're on the right track in that vigilance does deal with an ability of an operator. Unfortunately, attracting a fellow worker's attention is "way off base." Return to Page 42.

From Page 100

(2) You're wrong this time. Think this one through again. Return to Page 100.

- -

From Page 26

(2) This sound is much too intense. In fact, according to the DRC, 135 dB is the pain limit for unprotected ears, and exposure duration for 2.5 seconds or more can be harmful if the noise is over 300 Hz. Return to Page 26.

- -

From Page 84

(3) That statement is partially correct, but think about yourself in the design stage, and not as working with a system that's fully developed but not working properly. Return to Page 84.

- -

From Page 81

(2) Only half right; designing for the 50th percentile man is not a basic design principle. Return to Page 81.

- -

From Page 78

(3) This is an unrealistic answer. We bet you weren't serious when you chose this one. Right? Is it really feasible to make only low altitude flights? Return to Page 78.

From Page 51

(1) Increasing levels of intensity does affect performance. Return to Page 51.

From Page 79

(1) No, dB is the only measure we've discussed. Return to Page 79.

From Page 99

(1) Thirty MM HG is too high. It is, in fact, in the lower limits of the limited tolerance hot zone. By moving (from left to right) across the bottom of the graph, you can get to 30 MM HG. Then moving up from that point, you find the line meeting the lower bracketed end of the limited tolerance hot zone. Return to Page 99.

From Page 13

(2) The standards set by OSHA take the entire population of workers into account, even those who might not be in excellent condition. Servicemen are usually in excellent condition and, therefore, could tolerate higher exposures for limited durations. You chose correctly.

Thus, while MIL-HDBK-759 recognizes OSHA's standards for test and evaluation of personnel, it also emphasizes that design criteria for tanks should consider that OSHA's time-weighted average was based on risks of CO exposure to persons with unknown cardiac conditions; these risks do not apply to young, healthy servicemen. In fact, tests have shown that no significant effects on mental acuity or physical ability are noted with increases of 10 percent above OSHA's standards.

Aside from limiting the exposure time, you, as a human factors specialist, should give careful consideration to design. Ventilation must be provided in fighting vehicles so that noxious fumes will be below the levels at which they could have an adverse effect upon the individual. MIL-STD-1472 provided information on the amount of fresh air which is considered adequate in any personnel enclosure. This information can be found on Page 137. For example, according to this document, personnel compartments require at least 50 cubic feet of fresh air per minute per occupant to be considered sufficiently ventilated. In a later section you will review some of the protective measures that are taken when troops and crew are exposed to adverse chemical conditions. But for now, let's move on to radiation and its effects.

Only in the 20th century have machines been developed which are capable of releasing radiation particles. Space travel has placed mankind into a radiation environment different from that found on earth. With our short-term energy needs requiring greater use of nuclear power during the next 20-30 years, it is becoming more and more important to determine the tolerance of man for radiation. Man is comparatively radiosensitive. The lethal dose level for the human being is lower than that observed in most rodents.

(Go on to the next page)

From Page 19

Okay, you may not be too familiar with some of the terminology for describing radiation intensity, so we will give you some definitions:

(1) Roentgen is the basic indicator of the quantity of radiation found in the air.
(2) RAD (radiation absorbed dose) is the most common measure of exposure.
(3) REM (roentgen equivalent, man) is the most accurate unit for expressing exposure of man.

Most of our knowledge about the effects on man of whole body radiation come from data obtained on Japanese victims of World War II. The initial symptoms of radiation overdose involve nausea and vomiting. Figure 18.3 in your supplement shows the probability of nausea, vomiting, and death within 60 days as a function of increased radiation exposure.

What is the minimum RAD dosage necessary before there is an almost 100 percent probability of the nausea symptoms occurring?

(1) About 900 RADS. Turn to Page 35.
(2) About 250 RADS. Turn to Page 28.
(3) About 370 RADS. Turn to Page 23.

From Page 99

(4) Not all of these vapor pressure levels are acceptable, but two of them are within the proper limits. Return to Page 99.

From Page 80

(1) Correct. Most often, the hands, more than other areas of the body, are most affected by cold.

The next section concerns the effects of heat on performance. The most striking feature of our response to heat is the ability of the human being to adapt to it. Generally speaking, you would expect performance in heat to be affected by:

(1) The amount of heavy work to be done, the humidity level, and the amount of fluid lost from the body. Turn to Page 6.
(2) The humidity levels, air conditions BTU's, and additional CLO units. Turn to Page 1.
(3) The workload required of the operator and the effect of prior performance decrements. Turn to Page 4.

From Page 54

(1) This will help to minimize the effects of a cold environment, but in the long run there is a better method to use to enable people to tolerate severe cold weather. Return to Page 54.

From Page 81

(3) Right again. In general, you should design a system to suit either an extreme individual, and all others who are not as extreme (e.g., a system which takes into account a 300-pound person and all those weighing less), or one which fits an adjustable range of individuals (most often the 5th through 95th percentile).

Understanding anthropomentric data made it easier for you to start the ball rolling in designing work spaces. As you recall, you were introduced to guidelines to be used in design layout. There were four of these principles. What were they?

(1) Importance, frequency of use, sequence of use, and function. Turn to Page 85.
(2) Importance, frequency of use, sequence of use, and unusual individual operator differences. Turn to Page 26.
(3) Frequency of use, sequence of use, importance, and cost. Turn to Page 27.

From Page 4

(2) It appears that it is possible to adapt to CO if the build-up is slow; however, if it is rapid, then the detrimental effects mentioned will occur. Return to Page 4.

From Page 13

(1) The limits aren't outdated yet and they don't provide too little protection. In fact, their standards may be considered quite protective. Return to Page 13.

From Page 20

(3) Very good, at 370 RAD there is an almost 100 percent certainty that nausea will result. There also is a 50-50 change of death occurring.

In addition to the gases already mentioned and the radiation doses, there are other types of noxious substances which can be harmful to the hunam. Some of these are ammonia, aldehydes, and nitrogen oxides, as well as such thing as dust, fiberglass fibers, etc.

This next section will deal with the recommended ways to combat chemical warfare agents. There are three ways to provide protection against chemical warfare agents. First, there is individual protection, which generally consists of a protective mask, protective clothing, and a decontamination kit. What combinations of the three types mentioned above do you think are the most important for protective purposes?

(1) Protective clothing which minimizes radiation effects, and the decontamination kit. Turn to Page 44.
(2) Protective ensemble (protective mask and protective clothing). Turn to Page 39.
(3) The decontamination kit with antitoxins in it. Turn to Page 50.

From Page 58

(1) You are incorrect in assuming that conductive energy is one type of auditory transmittal system. Conductive energy is much too broad a concept (if it exists at all), because numerous transmittal systems can be said to 'conduct' the message. You are correct, however, in assuming that mechanical energy was one method of signal transmission. Return to Page 58.

From Page 63

(2) This was a tough one and you hit the nail right on the head.

Lesson 17 dealt with the effects of the environment on man's physiology and performance. You look at how the body reacts to change in temperature, as well as how it acts under extremes of heat and cold. By now, we think you'll agree with the statement that, as human factor engineers, we are concerned with designing environments (when possible) or equipment so that the individual can perform his job effectively, efficiently, and comfortably. To accomplish this, which of the following are of concern to you?

(1) Duration of exposure and intensity of the workload. Turn to Page 83.
(2) Temperature, humidity, and air movement. Turn to Page 75.
(3) Clothing requirements. Turn to Page 84.
(4) All of these. Turn to Page 74.

From Page 75

(1) Such an experimental design (where the type of clothing is the same) can say little about which clothing is best to use. Return to Page 75.

From Page 58

(3) Your answer is incorrect. Two types of energy transmission systems were discussed as being involved in transmitting sound waves from the outer ear to the brain. Return to Page 58.

From Page 89

(4) Very good, you're absolutely right. Over time, a person becomes less sensitive to certain noise levels.

So, PTS refers to a permanent loss. This loss tends to become increasingly greater with subsequent exposures to high sound intensities. This continued loss of hearing is well illustrated by Figure 19.4 in your supplement. While permanent threshold shifts can occur in anyone, some individual differences do exist. Figure 19.5 in the supplement shows the incidence of hearing impairment for several age groups of individuals who have been exposed to noise levels of different intensities. As can be seen, for individuals exposed to 85 dB, the impairment does not differ significantly from problems encountered by the general population. However, at higher intensity levels, the amount of impairment increases rapidly, except for the 20-29 year age group. (The general process of hearing decrement with age has been subtracted out for all age groups, and this does not affect the result shown here.)

You have dealt with a number of different types of noises that affect performance (either adversely or beneficially). Well, various types of noises affect hearing differently. For instance, steady, intermittent noise (such as the prolonged ringing of an alarm), and impulsive noise (such as the blast from a cannon) can levy heavy tolls in terms of hearing loss. In fact, in the case of impulsive noises, the toll is often levied fairly quickly. One study has shown that 45 gunnery instructors averaged 10 percent permanent hearing loss over a nine month period, even though most of them had used some sort of hearing protection devices.

We should also note, at this point, that impulse noise or blasts can have extremely detrimental effects on man. High intensity blast waves have been found to impact on gas-containing organs, such as ears, lungs, and intestines. The eardrum is susceptible to rupture when under pressure of about five pounds per square inch (PSI), while lungs can be damaged (to the point of hemorrhaging) at around 8-10 PSI. In addition, if you'll look at the table titled "Impulse Noise Limit Selection Criteria and the accompanying figure titled "Peak Pressure Level and B-Duration Limits for Impulse Noise," in MIL-STD-1474, you'll notice that the Army has certain hearing conservation criteria that must be met. The table lists noise limits by number of exposures that should not be exceeded (with or without protection). In addition, the Figure presents the peak pressure and duration limits. Of special interest to our currect discussion is the Z curve which deals with the limits that must not be surpassed to insure that no nonauditory physiological injuries will occur.

Thus far, we have discussed noise problems that range from mere distraction to severe, permanent damage. While it seems unlikely that we will ever completely eliminate noise and blast from our environment, we can attempt to control the impact of noise on man, or at least insure that the noise which reaches man's receptors is tolerable.

(Go on to the next page)

From Page 25

A number of ways by which man can attempt to deal with the problem of noise have been developed. For example, limiting background noise levels so as to minimize masking of speech communication (by, say, reducing the rumble of machinery) and also providing noise levels in work areas that do not interfere with performance are important safety precautions. In addition, using the concept of masking that we talked about earlier--loud, disruptive noises can be dealt with effectively by employing a low steady-state noise to mask the distracting impulse noise.

Over the years, noise exposure limits have been developed to provide a guide for the designer. These documents are referred to as damage-risk criteria (DRC) or damage-risk contours. These documents consist of lists pertaining to types of noise and the time limits involved for things such as extended space flights, ultrasonic impulse, and low-frequency noise limits. Figure 19.6 on Page 50 of the supplement gives you an idea of what such a DRC looks like.

This figure is pretty straight forward, but let's see if you're getting the idea of DRC's. Okay, what would you say was the maximum tolerable decibel level for an individual exposed to a 5,000 Hz noise for two hours?

(1) 110 decibels. Turn to Page 46.
(2) 135 decibels. Turn to Page 17.
(3) 100 decibels. Turn to Page 91.

From Page 92

(3) Your answer is incorrect. There is a correct answer given as a choice. Return to Page 92.

From Page 22

(2) You're close, but work space design does not take into account extraordinary operator differences. Return to Page 22.

From Page 84

(2) Excellent. You've obviously understood the key point of this section.

With a myriad of information available to the individual, he will have trouble operating properly unless you, as a designer, take into account his various information processing functions. Do you remember the three main areas of information processing that were discussed? What were they?

(1) Selective attention, personality, and channel capacities. Turn to Page 87.
(2) Selective attention, physiological processing limitations, and channel capacities. Turn to Page 71.
(3) Absolute thresholds, individual differences, and channel capacities. Turn to Page 15.

From Page 22

(3) This isn't the answer we had in mind, but you're not far off. Cost does play a vital role in the actual design process, but in this question, we wanted you to concentrate on the factors that produce the best possible design layouts. Cost will be addressed later. Return to Page 22.

From Page 97

(2) A counter would be a good type of display, but it's not static. Return to Page 97.

From Page 49

(1) Yes is the right answer and we appreciate the fact that you selected this answer. If this wasn't your first choice of responses, shame on you!

Well, when Eager got to the BOQ, he was not only frozen, but very proud. He had, after all, demonstrated that this edition of his perfect helicopter was nearly perfect. In his excited and happy state, Eager went off at a fast clip to find the senior officer in charge so that he could offer Eager the same kind of congratulations that Eager was offering himself. However, (there always is a however, isn't there?), as Eager rounded a corner, he noticed a defective cannister of tear gas, which had been inadvertently left in the middle of the walkway. You may be wondering what a tear gas cannister was doing in the middle of the hallway at the BOQ. We don't even know that ourselves, but in Eager's dream, it isn't too odd, is it? In any event, the cannister was defective and had begun to leak. Our eager young Lieutenant immediately sounded the alarm by yelling, "gas-masks on, everyone!" Tune in to the next lesson to see how Eager handles this situation...bye! Turn to Page 77 to begin Lesson 18.

From Page 20

(2) At 250 RAD there is only about a 45 percent probability of nausea occurring. At this level the probability of death is about 25 percent. Return to Page 20.

From Page 96

(1) So, that term may sound right, but it's not. Return to Page 96.

From Page 97

(3) Exactly right. You'd use a dynamic display since your data are constantly changing and a counter or digital display since you need precision.

Lesson 10 examined the value of using auditory displays and alarms. What would be some considerations which would indicate the use of auditory displays?

(1) The fact that the visual system is overburdened. Turn to Page 31.
(2) The operator is blind. Turn to Page 42.
(3) The message is short, simple, and calls for immediate action. Turn to Page 40.
(4) All of these. Turn to Page 33.

From Page 22

(3) This isn't the answer we had in mind, but you're really not far off. Cost does play a vital role in the actual design process, but in this question, we wanted you to concentrate on the factors that produce the best possible design layouts. Cost will be addressed later. Return to Page 22.

From Page 73

(4) While intense, continuous noise would definitely detract from performance, it is not the most distracting condition presented. Return to Page 73.

From Page 68

(3) We do adjust faster to very hot climates than to very cold ones.

In extreme heat, much acclimatization occurs within one week. By the end of the second week of exposure, a human being is just about fully adjusted. In extreme cold, however, the process takes a much greater length of time. While quite a bit of acclimatization takes place in the first week, it may take months or years to become fully acclimatized to extreme cold. Think about it, couldn't you become adjusted to the temperatures in South America much more rapidly than to the frigid conditions at the South Pole? You'd better believe you could!! After all, it is easier to get adjusted to temperatures which are 10 and 15 degrees greater than your body temperature of 98.6°F than it is to adjust to climates with temperatures 100° less than your body temperature.

Now, you need to know that it is not just the temperature alone which affects your reaction (bodily and psychologically); other factors contribute as well. Which of the following is another contributing factor?

(1) Both of these. Turn to Page 69.
(2) Air humidity. Turn to Page 60.
(3) Air movement. Turn to Page 58.

From Page 4

(3) You may be undecided, but just as 'almost' only counts in horseshoes, 'undecided' only counts in political polls. Return to Page 4.

From Page 51

(3) Increasing intensity does not adversely affect performance. Return to Page 51.

From Page 8

(3) How did you arrive at this answer? Our senses have known anytime we've ever used ammonia. This certainly isn't undetectable. Return to Page 8.

From Page 81

(1) Only half right; designing for the population's statistical mean is not a basic design principle. Return to Page 81.

From Page 96

(3) No, we've never even heard the term before! Return to Page 96.

From Page 29

(1) Reducing the burden of one sense is a signal for using another, but there are other good reasons listed here. Return to Page 29.

From Page 10

(2) Very good. It's apparent that you've learned how to use the table.

Okay, by matching the distance and the frequency you arrive at a minimum level of 67 dB, right? We hope you feel comfortable moving in and out of this table now. In fact, it also would probably be a good idea to be familiar with the information given in MIL-HDBK-759, which has a whole section covering noise effects.

Well, let's move on to a discussion of the ways noise can affect people physiologically. We will start by discussing some of the causes and results of what is known as temporary threshold shift. This concept refers to the fact that the minimum threshold required to hear a sound can be raised (i.e., a noise that was previously barely detectable can now no longer be heard) by continued exposure to an excessively loud noise. The amount of temporary threshold shift (TTS) is actually a complex function of such variables as the intensity and duration of the stimulation, the duration of intervals between exposures, and auditory frequency of the stimulus. Depending on the amount and combination of these variables present, TTS may last from several minutes to several hours to several days. Now, considering what you've just read, what would you say is the major difference between TTS and noise annoyance?

(1) The major difference between annoyance and TTS is the loudness of the noise. Turn to Page 96.
(2) While annoyance refers to the psychological effect noise has on performance, TTS is a physiological change that results from noise. Turn to Page 89.
(3) While annoyance refers to a physiological effect that results, there are no real differences between the two concepts. Turn to Page 98.

From Page 63

(1) Close, but research has shown that short rest periods are more effective in maintaining overall performance levels than one long one. Return to Page 63.

- -

From Page 29

(2) Exactly right. All of these should tell you to use an auditory display.

Once you've decided to use an auditory display, there are four general factors to consider:

(1) Compatibility - the use of typical population stereotypes.
(2) Approximation - when working with complex information, first use an attention-getter, then present the information-carrying signal.
(3) Dissociability - be sure the signal is easily discriminated from other signals.
(4) Invariance - use the same signal to describe the same information all the time.

Lessons 11 through 14 examined the concept of control design. The following checklist summarizes the key questions involved in control design:

(1) Have you chosen the best type of control? The broad types discussed were continuous adjustment and discrete setting. The advantages and disadvantages of these broad categories, as well as some of the more specific types, were presented to you as Table 11.1 in your supplement.
(2) Is the control the right size? Can the operator find it? Does it allow for adequate movement?
(3) Are the operating force, extent of movement, and speed of movement correct? How much pressure is required to operate this control? Have you selected the right body part to activate or operate this control? Is there enough room to move the control as much as is required? How fast does the control have to be moved? Can the operator more that fast?
(4) Have you provided proper body support?
(5) Is the direction of movement correct? Do you push forward to go forward? Up to increase speed? (Do you have S-R compatibility?)
(6) Are the control-display ratios correct? Is the ratio of movement of the control device to the movement of the display indicator compatible? As you turn the control dial, does the display indicator move the amount expected?
(7) Is the control correctly coded? Have you used the accepted coding techniques (color, location, labelling, shape, and size) properly? Did you use red for emergency? Are controls which are used sequentially located close to one another?
(8) Have you considered environmental factors? Can the operator utilize his equipment if he has heavy clothing on, or if he's sweating?

(Go on to the next page)

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From Page 33

These lessons, which covered a great deal of information, referred repeatedly to two military specifications. They were:

(1) MIL-STD-1472B and MIL-HDBK-759. Turn to Page 46.
(2) MIL-STD-1474B and MIL-HDBK-759. Turn to Page 50.
(3) MIL-STD-1472B and FED-STD-595. Turn to Page 54.

From Page 76

(2) While understanding man's capabilities and limitations is, indeed, an objective of this course, this understanding is but one piece of information necessary for solving the entire problem. Return to Page 76.

From Page 97

(1) You need a dynamic display since your data are constantly changing, but a moving scale with a fixed counter may require subjective estimates by the operator and is, therefore, not so precise as another choice you have available. Return to Page 97.

From Page 38

(2) Very good. Human Engineering is required to deal with man's attributes, and there is no set method for measuring some of these.

Not fully convincing Eager, CPT. Smart continued telling him about Human Factors. He told him that the human factors engineer's main concern was human effectiveness in a system. Human factors engineers deal with job designs, job aids, training material development, and selection and training of personnel. One of the key topics to which Eager was introduced was the concept of the man-machine system. What is the relevance of this topic to a human factors engineer?

(1) Trade-offs must often take place wherein the human factors engineer must 'compromise' between what might be optimal and what might be affordable. Turn to Page 86.
(2) In designing a system which integrates the human and equipment, human factors concerns must be analyzed. Turn to Page 60.
(3) In designing a system which integrated man and equipment, cost, reliability, safety, maintainability, and producibility must be considered. Turn to Page 83.
(4) All of these. Turn to Page 82.

From Page 20

(1) This dosage is so high the people exposed to it would be dead in a day or so. Try a lower estimate. Return to Page 20.

From Page 100

(3) Don't you think other things would serve more as distractors from optimum performance? Return to Page 100.

From Page 82

(2) Exactly right, these studies serve as an excellent argument for better Human Factors Engineering.

Lesson 3 closed with a review of the relative capabilities of men and machines. Since you've gone through this material in detail, which of the following general statements are true?

(1) Man is best at sensing unusual and unexpected events in the environment.
(2) Machines are more reliable for responding to an emergency.
(3) Machines are inflexible and usually inconsistent.
(4) Man is best at developing new solutions to problems.

(1) Statement (2) and (3) are true. Turn to Page 98.
(2) All statements are true. Turn to Page 93.
(3) Statements (1) and (4) are true. Turn to page 84.

From Page 13

(3) You pulled the wrong plug, one of these alternatives is correct. Return to Page 13.

From Page 42

(1) You're partially correct in that vigilance may involve being aware of the passage of time, but this answer does not really address itself to a general explanation of vigilance. Return to Page 42.

From Page 45

(1) Good, then let's do it. Your next lesson will deal with system acquisition. See you then.

From Page 10

(1) Your logic is faulty. Remember, you need to move down the nondetectability distance column to 500 meters, and across the frequency column to 8K. Return to Page 10.

From Page 92

(4) There is only one correct choice. Return to Page 92.

From Page 85

(3) No, that term was never introduced. Return to page 85.

From Page 76

(1) That's exactly right. The information you've learned thus far, coupled with what you'll get in the next 20 lessons, should start you on the road to understanding the importance of applying the concepts and priorities of Human Factors Engineering in your job.

After your introduction, you were confronted in Lesson 2 with the question, 'Why Human Factors?' You then met Lt. I. M. Eager, who has just been transferred to a Human Engineering Lab. He was a little weary of this assignment since he considered himself a hard scientist, and was unsure of the status of Human Engineering. The human factors engineer was a scientist, he figured, only if you stretch the word. (To ease his fears, his buddy-- CPT. Smart--told him that Human Factors is a "soft science.") Do you remember the main difficulty the human factors engineer confronts which is not encountered by other 'scientists'?

(1) Man is the subject of his science, and, since man is so unpredictable, the human factors engineer has difficulty making general statements. Turn to Page 65.
(2) He is required to deal with man's attributes and qualities which are not easily quantifiable. Turn to Page 35.
(3) The human factors engineer is involved with experts from many different fields and he must be able to reconcile many different points of view. Turn to Page 95.

From Page 89

(2) Severe tissue irritation is not the cause of a PTS. Return to Page 89.

From Page 23

(2) The protective ensemble is the most important piece of equipment. For ground troops, this is the only sensible way to provide protection.

The protective mask is issued to all military personnel during a combat-ready situation. It is possible to prevent entry of most chemical agents by filtering the air which is breathed. It is not to be used, however, as protection against carbon monoxide or other poisonous gases. These gases will pass through the filters. To protect individuals against these gases, an oxygen mask must be used. Do you see the difference between the two types of masks? The protective mask merely filters out some particles from the air you breathe, while the oxygen mask is hooked up to its own portable oxygen system.

Protective clothing, such as that which is impregnated with chemicals that neutralize most chemical agents, poses several problems in that it is uncomfortable to wear in temperatures above 70°F. One of the precautions issued with such equipment is that the wearer must be sprayed with water when temperatures are over 70°F in order for the wearer's tolerance time to remain constant.

From your previous lessons, you should remember that there are additional problems with protective clothing. What do these center on?

(1) Reduced functional efficiency. Turn to Page 62.
(2) Questionable protectability. Turn to Page 66.
(3) Extremely high monetary cost. Turn to Page 71.

From Page 2

(3) By this time all the pilots had put their masks on, but there is a better answer than this one. Return to Page 2.

From Page 51

(4) You have responded incorrectly. A correct answer has been provided. Return to Page 51.

From Page 29

(3) Short, simple messages which call for immediate action do fit well into auditory displays, but there are other good reasons listed here. Return to Page 29.

From Page 47

(1) This isn't enough. With a 5 degree increase the condition would still be too cool. Return to Page 47.

From Page 1

(2) Very good. These important physiological senses were dealt with in the context of human performance.

Now you'll have to admit that was a pretty easy question to start with, but we want you to keep refreshing your memory on the aspects of Human Factors Engineering you've covered thus far. In Lesson 14 several human senses were discussed, especially touch as it related to the design of equipment and alarm systems. In Lesson 15 you learned about the importance of the muscular sense and postural sensitivity in design.

In Lesson 16, you will read about another important area of concern to Human Factors Engineers, that of vigilance, or watch-keeping behavior. You will deal with the performance capabilities and limitations of the human in terms of continuous watch-keeping tasks. In addition, other aspects of human behavior will be presented, such as the effects of utilizing various work-rest schedules. Before we 'jump right in,' however, let's take another look at our hero, I. M. Eager, and the current state of helicopter affairs.

We discovered in the last lesson that Eager had succeeded in getting his helicopter airborne--and for more than just a few minutes this time. His confidence bolstered by this success, Eager decided to take his super helicopter on an extended test flight. On a whim (and having been born, raised, and educated in the 'sunny climes' of Florida--Eager was eager to see some different geography and feel a different climate), Eager set course for Alaska. Unfortunately for Eager, in his eagerness to test his helicopter in the 'wild blue yonder,' he left on this long journey without the benefit of his copilot.

Only after flying for some time did Eager realize his predicament, namely, that his ability to fly the helicopter is detrimentally affected by this extended flight. He began to notice that his performance declined as the duration of the flight and his 'duty period' increased. One of the things he noticed was that he began to miss the appearance of signals on his visual displays; i.e., his vigilance (or watch-keeping) was decreasing.

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From Page 41

As was discussed in several earlier lessons, human factors engineering began to grow in importance around World War II. This was also true with respect to the study of vigilance behavior. Since the beginning of World War II, there has been a growing technology pointing toward the development of electronic devices to increase the range of the human senses for target detection, especially in a military framework. Along with this interest, an increasing awareness has developed concerning the limitations of the human operator as a signal detector. This interest resulted in a further focus on the problem of human vigilance or watch-keeping performance.

To make sure you're with us on this discussion, we've decided to ask you to define vigilance as you've understood its meaning thus far. Is it:

(1) The ability of operators to detect the passage of time while on watch. Turn to Page 36.
(2) The ability of military personnel to stand guard for extended period of time. Turn to Page 55.
(3) The ability of operators to attract the attention of fellow workers. Turn to Page 16.
(4) The ability of operators to stay alert and detect the occurrence of infrequent signals. Turn to Page 7.

From Page 29

(2) Obviously, someone without sight will have no use for a visual display, but there are other good reasons for using auditory displays listed here. Return to Page 29.

From Page 78

(1) As a passenger, have you ever been issued chemical blood thinners? We don't think so. Return to Page 78.

From Page 5

(3) Good show, you've integrated these concepts well. The brighter the light, the more times the signal is presented, and the longer its duration all aid in maximizing signal detectability.

While the topic of characteristics of detectability, and their effects on vigilance are important, it is time that we moved on to another important aspect of vigilance. Thus far, we have dealt with the temporal course of vigilance performance, as well as the effects of display and signal characteristics. We would like to expose you to the relationship detween vigilance and (1) environmental conditions and (2) procedural conditions (such as the effective use of rest periods) and some methods of improving performance.

In dealing with the effects of environmental conditions, we will focus on two major variables: noise and atmospheric temperature. In terms of noise, numerous studies have focused on what effect, if any, loud background noise (of constant intensity) has on vigilance. The results from studies using simple vigilance tasks seem to point toward no real detrimental or beneficial effects of steady-state noise. However, environmental noise has reduced detection efficiency on vigilance tasks of a complex nature. Thus, when several displays must be monitored simultaneously where noises are present, detectability is reduced and response errors increase. Most of these studies dealt with loud environmental noises that ranged from 100-112 dB. Noise levels below this range did not adversely affect performance.

Atmospheric temperature has also been dealt with to determine its effect on watch-keeping behavior. In a classic study by Mackworth (1950), subjects were placed on watch under one of four temperature conditions (Incidentally, we're not trying to be 'name-droppers,' but for the students interested in vigilance research, Mackworth is probably the best source of relevant material on the topic that we can think of.). Anyway, the temperature conditions consisted of 70° ET, 79° ET, 87° ET, or 97° ET (ET or effective temperature was derived by combining the effects of temperature, humidity and air movement of warmth or cold felt by the human body.). It was found that overall watch-keeping performance was best at the effective temperature of 79°.

Results have also demonstrated that temperatures either above or below this level resulted in poorer performance. In fact, performance under the highest environmental temperature condition was not only poorer, but performance declined at a faster rate than under the moderate temperatures. So, as you can see, temperatures too much above or below a moderate temperature tend to hamper vigilance performance. Some studies have pointed to similar results under general 'work' conditions (i.e., in the

(Go on to the next page)

From Page 43

office), and therefore, such a factor should be taken into account in work space design. The following lesson (Lesson 17) will discuss such implications, and deal with whether temperature can severely affect overall performance directly or indirectly.

So far in our discussion of environmental conditions affecting vigilance, we have focused on temperature and noise, both important variables that must be taken into account. Now, by way of another question, let's review these environmental variables. Okay, in terms of the studies discussed in this section, which noise and temperature levels would impact most detrimentally on vigilance?

(1) A noise range of 100-112 dB and a temperature range of 97 degrees ET or higher. Turn to Page 59.
(2) A noise range of 97 degrees ET or higher, and a temperature range of 100-112 dB. Turn to Page 3.
(3) A noise range of 70 to 87 degrees ET. Turn to Page 11.
(4) A noise range of 10-112 dB and a temperature range of 70 degrees ET to 87 degrees ET. Turn to Page 93.

From Page 23

(1) What about protection for your lungs? Protective clothing won't prevent inhalation of noxious fumes and the kit won't correct the problem. Return to Page 23.

From Page 79

(3) Exactly right. TTS is an important concept and has many implications. Think of a weapons system or a space launch system. Both of these can produce tremendous noise. As a human factors engineer, you must be aware of its effect on the operator.

TTS, PTS (permanent threshold shift), and other distracting results of noise can be dealt with in various ways. The obvious solution is to reduce the noise level or design the system so the operator is not required to be near the noise. Quite often this is not possible. In such cases, hearing protection, such as earplugs or helmets, are used. But don't forget to account for the loss in hearing and speech intelligibility that such devices produce.

Well, that's about it for the first half of this course. In summary, you've examined many key issues relating to man's performance capabilities and limitations. The remainder of the course is divided into two major sections. The next 14 lessons will deal with how man fits into the overall system. You'll examine the system acquisition process, systems analysis, task analysis, and various training concerns. The final section of the course will tie all these concepts together and detail how human factors is applied in a military context.

And now, one last look at Lt. I. M. Eager. As you recall, Eager had just awakened from a dream in which many human factors errors had been committed. Luckily for Eager (and HFE in general), it was a dream (and a nightmare at that!). As Eager reflected on his nightmare, he began to realize that it was really a 'blessing in disguise,' for such real life mistake would be crushing blows to Eager's ego (to say nothing of this career). Eager has spent much of his career building a reputation as a bright, 'eager beaver,' and indeed he was. Thus being forewarned in his dream, Eager was spared much humiliation, for even though he was quite bright, many of these quandries--and mishaps could befall even smart folks like him, and me, and thee! But he had learned from his dream experience. He no longer thought that Human Factors Engineering was just common sense. He was anxious to learn more. How about you? Are you as 'eager' as Eager?

(1) Yes. Turn to Page 37.
(2) No. Turn to Page 98.

From Page 34

(1) Exactly right. The two key documents are MIL-STD-1472, 'Human Engineering Design Criteria for Military Systems, Equipment and Facilities,' and MIL-HDBK-759, 'Human Factors Engineering Design for Army Materiel.'

After the review of displays and controls was completed, a series of five lessons covered various topics relating to man's performance capabilities and the influence of various external inputs on these capabilities.

The first of these lessons (Lesson 15) dealt with the topic of vibration. Man's performance may be adversely affected by vibration. The performance capabilities of some people decrease as a result of vibration in a moving car; others can accept the spinning and turning of amusement park rides. Because there might be problems as a result of vibration effects, the human factors engineer must design with this in mind. Do you remember some ways to help get around this problem? What are they?

(1) Minimizing exposure time. Turn to Page 60.
(2) Using proper body posture. Turn to Page 50.
(3) Using proper seating design. Turn to Page 58.
(4) All of the answers listed here are correct. Turn to Page 63.

From Page 26

(1) You're not quite correct. We're looking for the maximum tolerable limits, and according to the figure, a 110 dB noise would be harmful if it was above 300 Hz and lasted for approximately 15 minutes. Return to Page 26.

From Page 70

(2) This is the temperature range that would make an individual feel most comfortable at this relative humidity level. Very good.

Here's another one to try. Suppose you were informed that the temperature range was between 60° (16°C) and 65° (18°C) and the RH was 20 percent. You determine that this is a moderately cool temperature and the people working in it are beginning to be uncomfortable. You can't do anything about the humidity level, but you can affect the temperature level. What do you do so that level results in a comfort zone level?

(1) Increase the temperature by 5 degrees. Turn to Page 40.
(2) Increase the temperature by 30 degrees. Turn to Page 61.
(3) Decrease the temperature by 10 degrees. Turn to Page 60.
(4) Increase the temperature by 15 degrees. Turn to Page 99.

From Page 100

(1) Your answer is incorrect. Think this question through again. Return to Page 100.

From Page 76

(3) Understanding military procedures is important, but it's not the main objective of this course. Return to Page 76.

From Page 1

(2) You've done it again. You're absolutely right in your answer. The relevancy of the stimuli is an important factor.

Thus, the relevancy of the sound is the controlling factor in whether it enhances or detracts from performance. We want you to be aware that the physical dimensions of noise (i.e., frequency, intensity) do play an important role.

When jobs require communication between co-workers, noise can (and often does) adversely affect performance. In general, speech sounds usually fall in the frequency range of 500 to 5,000 Hz. Noise at a particular frequency tends to interfere with speech sounds at the same frequency. This is because the particular speech frequencies that are also present in the noise are interfered with or 'masked' by the noise. Thus, in the area of audition, masking refers to:

(1) The interference of relevant frequency components by irrelevant (noise) frequencies at the same frequency. Turn to Page 52.
(2) The interference of speech frequencies below the level of the masking noise. Turn to Page 54.
(3) None of the answers is correct. Turn to Page 65.
(4) The inability of the speaker to talk loud enough to be heard over the noise of the traffic outside. Turn to Page 72.

From Page 63

(3) Some of these choices are opposites. How can they all be correct? Return to Page 63.

From Page 6

(3) Correct, the more physical the task, the more heat will affect your ability.

In general, heat stress adversely takes its greatest toll in performance in physical work activities. Mental activities may be impaired if the temperature is above 85°F (30°C) and the duration is longer than one hour. Otherwise, people can function adequately in heat if they must.

Of course, you must take into account such things as sweaty fingers and hands which manipulate knobs. A patterned texture will help maintain grip. Also, perspiration may obstruct vision and limit tactile sensation.

Well, it seems as though you have first been frozen and then fried, but we hope you can relate to some of the problems facing individuals who must work in these temperature conditions. The human reactions to these differing environments are so varied that just keeping an eye on the outside temperature will not be a very successful way of predicting performance levels. As a human factors engineer, you will have to keep, not only temperature, but humidity, air movement, durations of exposure, intensity of the workload, and clothing requirements in mind.

Aside from the possible effects of severe environmental conditions on work performance, as a human factors engineer, you will also have the comfort of the individual as a primary concern. The use of the figures in MIL-STD-1472 will be an invaluable aid to you in work efforts to help make the human comfortable in his surroundings.

Now, one last question: Are you eager to find out what is happening to Lt. I. M. Eager in his dream?

(1) Yes. Turn to Page 28.
(2) No. Turn to Page 52.

From Page 1

(1) Studies have been done which demonstrate how high frequencies can enhance or detract from performance. Return to Page 1.

From Page 23

(3) This isn't considered the most important piece of equipment. Antitoxins overcome the effects of poisons, but what about the need to prevent exposure by using masks and other types of equipment. Aren't these of primary concern? Return to Page 23.

From Page 1

(3) Your answer is not entirely correct. While the kinesthetic senses were dealt with, other concepts were presented as well. Return to Page 1.

From Page 34

(2) Half right; one of these deals with noise and doesn't really address control design. Return to Page 34.

From Page 46

(2) While it's true that proper body posture helps to reduce vibration, is this the best or only method the HF specialist can help reduce vibration? Return to Page 46.

From Page 7

(1) Quite right. The greatest performance decrement during any watch period usually occurs during the first 30-60 minutes of watch. This rapid decline in performance is widely referred to as the 'vigilance decrement.'

We hope that question wasn't confusing for you. There are two aspects of this question that needed to be taken into account when arriving at an answer. First, it was noted that a general decline in performance does occur over time. Also, however, in terms of magnitude of decline, we pointed out that this occurred in the first hour of watch, with much slower performance loss after that point.

Okay, now that you have reviewed the temporal course of vigilance, you need to look at how different display characteristics affect vigilance. While we have just noted that vigilance performance declines over time, some studies have shown that detection performance on complex tasks, where several clocks, signals, or dials must be monitored, tend to show little or no decrement as a function of time. In large part, this seems to be related to the degree of display compatibility; the higher the compatibility, the less the performance decrement. However, with increasing display complexity (holding compatibility constant across displays), you tend to find a lower overall proficiency level. This general trend of lower overall proficiency tends to hold for both visual and auditory watch-keeping tasks. Thus, with either sense modality, complex tasks shown lower proficiency, but no overall performance decrement with time.

Another important area under investigation that has been found to affect watch-keeping behavior involves the characteristics of the signal or signals being monitored. One characteristics that affects performance is intensity of the signal. What do you think can be said about the relationship between signal intensity and detectability?

(1) As long as the signal is above a minimum threshold level, increasing the intensity does not affect performance. Turn to Page 18.
(2) Given the same background noise level, the probability of detection increases as signal intensity increases (up to a point). Turn to Page 5.
(3) As long as the signal is above the minimum threshold level, increasing the intensity of the signal will adversely affect watch-keeping performance. Turn to Page 30.
(4) None of these answers is correct. Turn to Page 40.

From Page 48

(1) You're quite right. Noise levels at or above the frequency of the relevant sound tend to interfere with the ability to perceive that relevant sound.

Masking is, thus, the reduction in the sensitivity of the ear to one component of the sound environment by another component in the sound environment. In studying the effects of masking, the experimenter usually measures the minimum audible level of a sound when presented by itself; then measures that same level in the presence of the masker. The difference is then attributed to the masking effect.

Different types of maskers and masked sound (i.e., pure tones, complex sounds, white noise, speech) result in different degrees of masking. The nature of the masking effects depends largely upon the nature of the two sounds in question. In the masking effects of pure tones on pure tones, the effect is rather complex, with considerable variation. Still, figure 19.2 (in your supplement) demonstrates that masking is generally greatest in the frequencies surrounding the masking tone. This complexity does not hold true for the masking of pure tones by noise, however. By looking at Figure 19.3, what general conclusion can you draw about masking?

(1) The lower the frequency the greater the masking. Turn to page 86.
(2) The higher the frequency, the greater the masking. Turn to Page 81.
(3) The threshold of pure tones is increased by 15 to nearly 30 dB, with greatest increase at the higher frequencies. Turn to Page 73.
(4) Masking effect remains the same over all frequencies. Turn to Page 92.

From Page 49

(2) Aw, our feelings are hurt. But we forgive you. Return to Page 49.

From Page 99

(2) A vapor pressure of 20mm Hg is the highest level acceptable for a summer comfort zone. A winter comfort zone will require a vapor pressure of no more than approximately 17.5mm Hg. Very good.

People who work under extreme cold will develop performance deficits long before they are in danger of fatal exposures. These performance deficits are primarily in the areas of coordination and motor ability. However, this is a general statement; the effects on performance are related, not only to the cold temperature, but also the duration of exposure, the wind chill factor, and the amount of insulation used by the individual. Table 17.1 on Page 41 of your supplement presents the cooling effects of temperature and wind speed. Notice that for any air temperature as the wind speed increases, the equivalent temperature decreases. For example, if the air temperature is -10°F and the wind is blowing at 30 miles per hour, this is the equivalent of a calm -63°F air temperature. Pretty cold, isn't it?

One of the primary parts of the body to be adversely affected by cold is the hand. Hand skin temperature (HST) is the critical factor in determining the level of performance of manual tasks. This temperature must be maintained between 55 and 60°F for effective performance; for some types of fine motor tasks the HST may have to be higher. Various experimental findings report that as the HST falls below the critical region, individuals performing such manual tasks as typing, tying knots, or breaking down a brush assembly are worse than if the HST is above the critical region. Reaction time tasks, however, seem to be more affected by wind speed than air temperature.

Because people are needed to staff positions and billets which are located in cold climates, we need to investigate ways to either control the temperature, or design equipment to overcome the effects of the temperature. In cold temperatures, since HST is so important, one of the primary missions of a human factors expert would be to find ways to protect HST. Now the problem begins to complicate itself. Obviously, protective gear would help maintain HST at or above the critical region. However, this could lead to poor performance. Bulky gear is not conducive to dexterous performance. In designing a new piece of equipment, it is important to add the CLO factor to the established anthropometric data. In this way, if a series of knobs, for example, needs to be manipulated by a heavily gloved hand, you will have spaced these knobs far enough apart to accommodate the cold weather gear.

(Go on to the next page)

From Page 53

Exposure to cold weather, in and of itself, doesn't appear to affect adversely visual perception or mental tasks. You, as a human factors engineer, can suggest ways to help make the environment more tolerable to the individuals who will have to work in it. Which of the following do you think is the best action to take to accomplish this?

(1) Provide cold weather gear. Turn to Page 21.
(2) Provide a diet heavy in starch to increase bodily heat. Turn to Page 81.
(3) Promise people that their stay will not last longer than one year. Turn to Page 61.
(4) Permit people to become gradually acclimatized. Turn to Page 80.

From Page 34

(3) Half right; one of these only addresses color. Return to Page 34.

From Page 48

(2) You are not entirely correct. Primarily, a masker will mask a tone at about the same frequency, but it has been shown that high frequency tones can, in fact, mask low frequency tones. Return to Page 48.

From Page 64

(3) Well done. We're happy to see you integrating these concepts so well.

The literature shows that signal detectability is increased by utilizing an expert observer; this behavior is further enhanced by adding another observer. By instituting show watch periods and many short rest periods, performance is enhanced still further.

Before you 'polish off' another lesson, we'd like to ask one last question on vigilance that will present several other bits of information. Okay, which of the following statements best describes watch-keeping behavior?

(1) If the operator is told to report only signals he's very sure have occurred, frequency of correct detections may be reduced, but if this stringent requirement is eliminated, both correct and incorrect detections will increase. Turn to Page 59.
(2) If an operator is kept active or is a member of a team, his detection performance will be better than if he is monitoring in an impoverished environment. Turn to Page 80.
(3) If the operator has been trained with frequencies of signal occurrence different from those in the operational task, his performance will be poor. Turn to Page 66.
(4) All of these answers are correct. Turn to Page 90.

From Page 42

(2) While standing guard for extended periods of time may be an example of vigilance, this answer does not define what vigilance really is. Return to Page 42.

LESSON 19: NOISE, OR CAN YOU HEAR ME?

Hello, again. We're glad you're back for another lesson. Bet you can't believe you're almost half through with this course. Well, you are--this is Lesson 19. In this lesson you will learn how the human factors specialist should deal with the problem of noise exposure. The bulk of the material presented to you will revolve around the physiological and performance effects of different types of noise.

In addition, we will attempt to give you a broad introduction to the factors that are typically taken into account in evaluating noise effects. You will deal with the relationship between noise and hearing loss, as well as the effects of noise on performance and one's ability to communicate with others. If it sounds like we've got a lot to cover in this lesson, you're right, which means we better get started right away.

By way of introduction, let's check back in on Lt. I. M. Eager and see how he is faring. Eager, having pronounced the maiden voyage of the super helicopter a 'grand success,' was eager to return to his home base, where the helicopter had been designed. Everyone involved with the design and construction of Eager's helicopters had been notified of his success and his expected time of arrival back at the base. On the flight (this time appropriate crew members were aboard) Eager daydreamed of the 'homecoming' celebration which he anticipated.

This was, indeed, a proud moment for our hero, as the helicopter slowly settled on the tarmac, Eager's heart began to beat rapidly, his eyes began to water, and his palms began to sweat. Smiling and waving as he emerged from the super helicopter, Eager was greeted by a 21-gun salute, which produced a ringing in his ears and a temporary loss of hearing. Because of this hearing loss, the accolades directed toward Eager fell on deaf ears (so to speak). Now, wasn't that a smooth transition from the saga of I. M. Eager to a discussion of noise?

Let's begin our discussion of noise by clarifying exactly what we mean by noise. In general, noise is any auditory stimulus that has no real informational relationship to task completion. Keep this definition of noise in mind in our discussions throughout this lesson. The supplement for this lesson includes several important figures and tables that we will be referring to from time to time, so, be aware of that source of information as well.

(Go on to the next page)

From Page 56

Before we can proceed with an in-depth discussion of noise, you need to become familiar with some of the literature on the physiology of hearing. A knowledge of the processes involved in hearing is a necessary foundation, because one must take into account the capabilities and limitations of man's auditory system in any discussion of noise.

Let's begin by discussing the structure of the auditory system. The ear has three basic anatomical subdivisions, which contain all of the conductive (and some of the nerve) elements of the hearing mechanism. Figure 19.1 in your supplement gives you a cross-sectional view of the human ear. The outer ear consists of the pinna (the fleshy, cartilaginous external portion) and the auditory canal (which leads inward to the middle ear). The auditory canal is bounded on the interior end by the eardrum, or tympanic membrane, which is, thus, the point of separation between the outer and middle ear. The middle ear contains a chain of the small bones (the hammer, anvil, and stirrup) which form the sound conduction system between the middle and inner ear. This boney conduction system is often referred to as the ossicle.

The stirrup, or final bone in this chain, is connected to the oval window which separates the middle and inner ear. The inner ear (called the cochlea) is a closed, fluid-filled chamber that resembles a snail with its spiral shape. Structures of prime importance in the inner ear are the basilar membrane, organ of corti, and round window (which is at the end of the cochlea furthest from the oval window).

Sound is transferred from the outer ear to the brain in the following manner: sound is picked up by the outer ear and reflected inward to the membraneous eardrum. At this point, some of the sound waves that strike the tympanum are reflected back into the auditory canal. The rest are transmitted across the membrane to the air-filled middle ear. This sound pressure is then transferred in the vibratory manner across the bones of the middle ear, to the foot of the stirrup, which rocks to and fro, delivering the sound vibration to the fluid of the inner ear. The stirrup thus acts like a piston, driving the fluid back and forth in the rhythn of the sound pressure.

These fluid movements force the basilar membrane (within the cochlea) into vibration, which transmits these signals to the hair cells and nerve endings of the organ of corti (these hair cells being sensitive to very slight changes in pressures). The neural impulses sensed by these nerve endings are then transmitted to the brain via the auditory nerve.

(Go to the next page)

From Page 57

Okay, taking into account the entire auditory process from the time sound waves enter the auditory canal to the time electrical impulses are sent to the brain, two types of energy transmission systems are utilized. From what has been said, can you determine two mechanisms the auditory system utilizes to transmsit sound waves to the brain?

(1) Mechanical energy and conductive energy. Turn to Page 23.
(2) Electrical energy and bone conduction. Turn to Page 12.
(3) None of these choices are correct. Turn to Page 24.
(4) Mechanical energy and electrical energy. Turn to Page 9.

From Page 46

(3) You're correct in assuming that proper seating design helps reduce vibration, but there is more that can be done by the human factors specialist. Return to Page 46.

From Page 30

(3) The air movement is a factor, but it isn't the only one. Return to Page 30.

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From Page 44

(1) You're quite right. A noise range of 100-112 dB was shown to affect vigilance detrimentally, as was a temperature that approaches 97° ET or higher.

We'll now deal with another important set of variables that affect vigilance, namely, procedural conditions. In this section you'll be exposed to how variations in the watch-keeping situation affect that behavior. One area that has been investigated rather extensively is the rest interval between watches. Both lengths of the rest interval, as well as a number of rest intervals, have been studied. Wouldn't it seem reasonable to expect that reducing the period of continuous watch by introducing rest intervals periodically would reduce or even halt the decline in vigilance performance? This, in fact, has been found to be the case.

Probably the biggest question that remains is not whether rest periods have the effect of maintaining watch-keeping at initial levels, but whether one number and duration of rest intervals is better than another. Based on what you have been exposed to concerning rest intervals so far, what would you think would be a good combination of these intervals?

(1) One long rest interval between watches is better than a number of short rest periods. Turn to Page 83.
(2) Several relatively short rest periods throughout a vigilance task are more effective in maintaining overall performance levels than one long rest period between watches. Turn to Page 100.
(3) There is no significant difference between these two strategies. Turn to Page 64.

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From Page 55

(1) You're right, but a better answer is provided. Return to Page 55.

- -

From Page 35

(2) This is true, but aren't the other statements also true? Return to Page 35.

From Page 46

(1) It's true that the less exposure to vibration increases the chances of good performance, but there are other things that can be done by the HF specialist. Return to Page 46.

From Page 30

(2) The air humidity is a factor, but isn't the only one. Return to Page 30.

From Page 47

(3) If you were already cold to begin with, why would you lower the temperature? You seem to be exhibiting a kind of dry-ice humor. Return to Page 47.

From Page 68

(2) Nice try, but this is not so. It takes longer to get acclimatized to extreme cold. Return to Page 68.

From Page 70

(1) This is the temperature range that would be established if you wanted a slightly cool environment. Did you perhaps go too far to the left in your intercepts? Return to Page 70.

From Page 47

(2) This is too much of an increase. If you raised the temperature by 30 degrees, the range would be 90 degrees to 295 degrees F. While this wouldn't be too bad at the low humidity level, it is still too hot for the comfortable zone. Return to Page 47.

From Page 54

(3) This may work to get the individuals to the work site, but it isn't the best strategy to use if you want to help him tolerate the environment better. Return to Page 54.

From Page 39

(1) Now you're cooking. We bet you remember that in past lessons we addressed the issue of protective clothing and how it might interfere with performance because of its bulkiness.

Besides reducing an individual's dexerity and imposing the problem of heat, another area of concern when using protective clothing is the possible loss of visual field. The lens in the mask may fog and, therefore, reduce the wearer's visual capabilities.

The second method of protecting against chemical warfare agents is the collective protection for the crew station. This means that each crew member wears a protective mask, but instead of having individual particle filters, the operators use a central located gas particulate filter. Now, can you tell which of the following types of stations or crews would best be served by the crew-station collective protection method?

(1) Infantry troops. Turn to Page 85.
(2) A computer center. Turn to Page 79.
(3) A tank crew. Turn to Page 75.

From Page 1

(1) It's true, we discussed man's sensitivity to motion in a recent chapter, but that's not all that we've dealt with. Return to Page 1.

From Page 46

(4) Well done. Standing will allow absorption of vibration; if seats are designed with an absorbing material, vibrations will be reduced; if all else fails, don't expose the operator for a longer period than he can handle.

Lesson 16 dealt with the question of vigilance. Vigilance refers to the ability of the operators to stay alert. As designers of military systems, we are highly concerned with vigilance. As the Coast Guard says, 'Semper Paratus,' 'Always Prepared.' As a summary of the vigilance research, several general statements may be made. Which of the following statement are true?

(1) The greatest performance decrements occur during the first 30-60 minutes of watch.
(2) The smallest performance decrement occurs during the first 30-60 minutes of watch.
(3) There is an 'end-spurt' at the end of a watch where a slight increase in performance occurs.
(4) Very high temperatures (97° ET and above) affect vigilance adversely.
(5) One long rest period between watches is better than several short ones.

(1) (1), (3), (4) and (5) are correct. Turn to Page 32.
(2) (1), (3), and (4) are correct. Turn to Page 24.
(3) All are correct. Turn to Page 48.
(4) (1), (3), and (5) are correct. Turn to Page 72.

From Page 1

(3) Adequately designed studies have been conducted which shed light on the reason for these findings. Return to Page 1.

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From Page 100

(4) Good show, we're proud of you; you reasoned that out very well. While various watch lengths and rest interval were presented, none of them have been shown to aid vigilance performance.

So, as we mentioned, studies have shown that performance could be improved by having the subject stand shorter periods of watch. For example, Mackworth (1948) has shown that having two observers alternate the watch in 30-minutes shifts was superior to alternating in 60-minutes shifts.

We'd like to mention some suggested methods of improving performance, and in doing so, review some variables already discussed that affect vigilance. One suggestion that has been mentioned is to use more than one observer. It has been found that when multiple observers have monitored the display, the total number of detections increases. Similarly, we have discussed the need for frequent rest periods, maintenance of beneficial environmental temperature and noise levels, as well as the need for increasing beyond threshold levels the detectability of signals. In addition, performance has been shown to be enhanced by using expert observers, and also by providing immediate feedback as to the correctness of the response.

Thus, which of the following situations would you believe to be most beneficial in terms of signal detection?

(1) Several observers teamed together working on a number of short watch periods separated by short rest periods. Turn to Page 79.
(2) Several observers working on several long watch periods, each separated by short rest intervals. Turn to Page 94.
(3) Several expert observers teamed together on a schedule with a number of short watch period separated by short rest intervals. Turn to Page 55.

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From Page 59

(3) One is better than the others. Return to Page 59.

- -

From Page 48

(3) One of these answers is indeed correct. Return to Page 48.

From Page 100

(4) Your answer is incorrect. Think this question through again. Return to Page 100.

From Page 38

(1) While this statement by itself may be true, it is not the main difficulty confronting the HF specialist. Return to Page 38.

From Page 85

(2) No, that term was never introduced. Return to Page 85.

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From Page 39

(2) Protective clothing increases the operator's ability to work, free from harm, in such environments. Return to Page 39.

- -

From Page 55

(3) You're right, but there is a better answer. Return to Page 55.

- -

From Page 68

(1) We don't get acclimatized to both extreme temperatures in the same length of time. Return to Page 68.

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LESSON 17: TEMPERATURE EFFECTS, OR BABY, IT'S COLD OUTSIDE

Hi, welcome back to your Human Factors Engineering Course. If you recall, Eager had finally been given an assignment for his perfect helicopter. He had demonstrated that it was capable of sustained flight by flying it to a military base on the frozen tundra. This time Eager was prepared...he had designed his machine with temperature change factors in mind. The perfect chopper could operate as effectively in hot or frigid climates at it could in moderate or temperate ones. In his eagerness to serve, however, Eager had not had time to pack some additional clothing. As the helicopter landed on the frozen surface, the fact became quite apparent. Eager stepped out of the chopper, was hit with a blast of cold air, and immediately ran for the nearest shelter...an igloo-fashioned BOQ.

Okay, you probably want to know what this lesson will cover. Lesson 17 will deal with the effects of environmental temperatures on man's physiology and performance. First, you will learn about the body changes which occur during exposure to extreme temperatures. Next, we will discuss how the individual becomes acclimatized (used to) thermal changes. You will also learn about effective temperture indexes, which will be an aid for you in your job as a human factors engineer. In the second section of this lesson you will learn about the effects of extremely cold temperatures in terms of bodily reactions and performance. Finally, in the third section of this lesson, we will talk about heat stress and its effects. So, without further ado, let's begin.

The human being has developed a substantial ability to adapt to the environmental variables within his world. When the body moves from one thermal condition to another, there are changes which occur within the body.

When you go from a nice warm environment into a cold one, adjustments occur in your body. Some of these are (1) the skin becomes cool; (2) your blood is routed away from your skin and toward the more central parts of your body so that it can be warmed before going back to the skin area. Isn't that nice. You are, in effect, your own portable heater! (3) Shivering and 'goose flesh' may also occur in order to increase skeletal muscle activity which, in turn, increases heat production.

When you go from a cool environmental temperature into a warm one, your body adapts by performing the reverse adjustments. Your skin has a higher temperature because the blood is being routed to it so it can be cooled down. Your body also begins to sweat to reduce its temperature.

(Go on to the next page)

From Page 67

Adaptation is the term used to describe these physiological adjustment processes that take place when you are exposed to varying thermal changes. If an individual is habitually exposed to extreme temperature conditions, then a series of physiological adjustments occur. This process is called acclimatization and could be considered a somewhat long-term adaptation.

Habituation and sensitization are psychological terms which reflect an individual's willingness to tolerate a situation after being exposed to it. Habituation can be likened to familiarity, which, in turn, usually leads to a greater acceptance or tolerance of the situation. Sensitization, on the other hand, typically means that the individual has a lower tolerance level for the situation and is more likely to refuse to be exposed to the situation for any duration. As human factors engineers, we should assume that the individual in question is unadapted and unhabituated when he first enters the scene. In so doing, we can hope to design an environment (or equipment to use in an environment) which will result in the greatest amount of habituation, acceptance, and comfort, and the least amount of sensitization required of the operator.

Now, take a stab at this question. Which takes the least amount of time to get acclimated to, extreme heat or extreme cold?

(1) Both extreme heat and extreme cold require about the same length of time to become acclimated to. Turn to Page 66.
(2) Extreme cold. Turn to Page 61.
(3) Extreme heat. Turn to Page 30.

From Page 30

(1) Right on, both of these factors influence our reaction to the surrounding atmospheric environment.

Factors such as humidity and air movement, as well as the radiant temperature of the walls and other surfaces, all interact with the temperature to influence the body's reaction to the atmospheric environment. Table 17.1 shows the effect of wind on temperature (you've heard of the wind-chill index?). The body loses heat to the environment primarily by evaporation (sweating) when the temperature is hot. If the humidity level is also high, then this has a limiting effect on the evaporation process. If the temperature is very cold and there is high humidity, the individual is more uncomfortably cold than when the humidity is lower.

Air movement also helps make the body more comfortable in hot climates, because it exposes the surface of the body to more air. This, in turn, aids the evaporation process. However, in freezing temperatures or below, the air movement (wind chill) is the factor which makes the individual very uncomfortable and more susceptible to adverse effects, such as frost bite.

The process of heat-exchange is influenced, not only by the above factors, but also by the amount of insulation that our clothing provides. A term used to measure such insulating effects is a 'CLO.' A unit of CLO is a measure of the insulation necessary to have a seated, resting person feel comfortable in a room that has a 70°F (21°C) temperature with 50 percent relative humidity. For every 16 degrees of temperature drop, one CLO unit should be added to maintain this comfort level.

Okay, so far you've learned quite a bit of basic material. Physiological and psychological reactions to the environment have been related to you. Various factors, such as humidity and air movement, which influence these reactions have also been discussed. Now, let's see if we can't tie some of these things together.

(Go on to the next page)

From Page 69

What we as human factors engineers are primarily concerned with is designing environments (when possible) or environmental equipment so that the individual can perform his job requirements effectively, efficiently, and comfortably. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has developed an effective temperature scale which combines the effect of temperature and humidity. This scale is called the ET (effective temperature) scale. The ET scale is in your supplement on Page 42. Please refer to this scale for the following discussion.

Any ET is equal to the sensation which is produced by a dry-bulb temperature of the same amount in 50 percent relative humidity. For example, an ET of 70 percent is equal to a dry-bulb temperature of 70° in 50 percent RH. It is also equal to about 72°F when the relative humidity is 10 percent. Figure 17.1 in your supplement is the ET scale. If you will notice, those combinations of conditions which provide comfort zones are noted on the figure. We would like to give you some practice in using this graph. On the X or bottom axis, dry bulb temperature is measured in both farenheit and centigrade scales. The Y or side axis represents the level of water vapor pressure units. Within the graphs, the ET and comfort zones are plotted as they are affected by these two factors and relative humidity.

For example, a comfortable zone for 10 percent RH would require temperatures between about 78° (25°C) to 84° (29°C). To determine what the temperature must be for comfort, first determine the relative humidity that exists in the environment, then find that RH percent line on the graph and follow it until it intersects with the first vertical line, determining the comfort zone. Next, drop a straight line from this interset to the X axis. Repeat this step for the other side of the comfort zone and you will have determined the range of temperature values to use to ensure the comfort of the individual at this humidity level.

Now, this may sound complicated, but it really isn't. Let's try a couple of problems so you can practice using this graph. First, if the RH is 80 percent, what is the temperature range (in fahrenheit) that should be established for comfort?

(1) 70-73. Turn to Page 61.
(2) 75-78. Turn to Page 47.
(3) 60-65. Turn to Page 11.

From Page 27

(2) Right on. These are three of the main concerns of a human factors engineer when he thinks about human information processing.

When you're designing a system, then you must be sure that you don't expect man to perform beyond his physiological capabilities (e.g., hear a signal above 20,000 CPS). Don't give him too much information 'on one channel,' and be sure your system takes into account the fact that certain stimuli are more readily attended to than others (selective attention).

Lesson 5 took a step back from theory to deal with the history of this science and bring together the key ideas of the first few lessons.

Then, in Lesson 6 you got into some real human engineering working data. In this lesson we talked about anthropometry, or the science of dealing with the measurement and physical features and functions of the body. An important emphasis on this lesson was that man's physical dimensions are important aspects of any man-machine interface and must be considered very early in the design stages of the process. Lesson 7 showed you how to take this data and put it to work in a real-life setting. First, you looked at anthropometric data; you were introduced to functional and structural body dimensions. What is the major difference between these two types of dimensions.

(1) Functional dimensions are measured with an individual in a fixed position; structural dimensions are determined from body positions which occur with movement. Turn to Page 12.
(2) Structural dimensions are measured with an individual in a fixed position; functional dimensions are determined from body positions which occur with movement. Turn to Page 81.
(3) Structural dimensions deal with man's genetically derived physique; while functional dimensions involve how man is able to function within these physiological limitations. Turn to Page 15.

From Page 39

(3) While such clothing is definitely more expensive than normal clothes, this isn't the biggest problem. Return to Page 39.

From Page 48

(4) While this might well be an example of the traffic noise masking speech, it is not a definition of the 'masking' concept. Return to Page 48.

From Page 63

(4) Close, but research has shown that short rest periods are more effective in maintaining overall performance levels than one long one. Return to Page 63.

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From Page 52

(3) Quite right, an increase of 15 or 30 dB is necessary to raise the pure tones to an audible level when masked by noise. In addition, the largest increase in dB level is required for higher frequency tones.

Because specific noise levels (determined by frequency and intensity) interfere with communication, certain procedures have been developed that predict the interfering properties of noise levels. Articulation scores (from an articulation index) are commonly used to define intensities of noise that interfere with levels of communication (or speech interference levels). These methods can be used to predict how noise will interfere with job performance when speech communication between workers is necessary. Calculation of these levels of interference or articulation is rather complex and too detailed to be adequately presented here. However, we want you to be aware of this source of information in case you need to refer to it at any future time. A good coverage of articulation index (AI) interpretation can be found in the 'Human Engineering Guide to Equipment Design' By H. P. Van Cott and R. G. Kinkade.

Before we move on to a general discussion of problems created by noise, we would like to expose you to how changes in noise levels affect performance. Accumulated evidence points to the fact that changes in the prevailing noise level might affect performance more drastically than would a constant absolute level of noise. Furthermore, the loss in proficiency on a task was found to be proportional to the amount of change in the noise level, regardless of whether the level was increased or decreased. Thus, a large change in noise level would result in greater performance decrement than would a small noise level change. Now, taking into account what has been said earlier, which of the following situations would most detract from performance?

(1) Soft, intermittent noise. Turn to Page 15.
(2) Soft, continuous noise levels. Turn to Page 3.
(3) Intense, intermittent noise. Turn to Page 10.
(4) Intense, continuous noise. Turn to Page 29.

- -

From Page 24

(4) You've learned well. The temperature and relative humidity combine to give you an effective temperature. The movement of air can help when it's too hot, hurt when it's cold. The longer you are exposed to certain temperatures, the better, because you become acclimated. Long-term exposure to extreme temperatures, however, will have debilitating effects in extreme heat, (because man's ability to perform will decrease as workload increases under these conditions). Finally, the proper use of clothing can offset several of these problems.

In Lesson 18 you learned about atmospheric effects on the human. As you saw, the human factors engineer really can't do a great deal to control the atmosphere. The effects of too much carbon monoxide are terribly detrimental to human health. What can a human factors engineer do about it?

(1) All of these. Turn to Page 79.
(2) Design so that toxic fumes are ventilated well. Turn to Page 86.
(3) Provide protective gear for the operator. Turn to Page 87.
(4) Design so that chances of exposure to toxic substances are slight. Turn to Page 93.

From Page 89

(1) While it might be true that prolonged exposure to noise could eventually result in all of the conditions, normal loss of sensitivity would occur much more rapidly than the noise intensity and/or duration required to cause bone shattering or tissue irritation. Return to Page 89.

From Page 62

(3) Very good. This is, in fact, the example used in MIL-HDBK-759.

The tank crew has traditionally been protected by the crew-station collective protection method. The third method of protecting against chemical agents is called the collective protection-overpressure method. In this case, the protective system eliminates the requirement for masks and other protective gear. The overpressure system also allows the operators within the system to continue at their tasks and to be fully mobile while within the system. This method also has the advantage of minimizing the danger of contamination of the equipment within the overpressurized system. Of course, this type of protection cannot be available when the system is mobile. Therefore, ground troops will not have the availability of such a system.

Now let's find out where the human factors specialist fits in all this. First, as a human factors specialist, you might be required to conduct some tests to evaluate the performance of operators while they work in a toxic environment (with appropriate protective gear) and while they work in a nontoxic environment. What do you think the results of such tests should tell the human factors engineer?

(1) The types of protective gear needed by an individual. Turn to Page 24.
(2) The absolute amount of work an individual is capable of performing in toxic conditions but not in nontoxic environments. Turn to Page 16.
(3) The difference between performance capabilities of the operators in the toxic and nontoxic environments. Turn to Page 14.

From Page 24

(2) You're quite right in assuming that temperature, humidity, and air movement affect man's performance, but there is another answer provided that more fully answers the question. Return to Page 24.

HUMAN FACTORS ENGINEERING

LESSON 20: REVIEW

Well, here you are at the half-way mark. You've completed 19 of the 40 lessons, having just completed the section concerning 'Human Capabilities and Limitations.' You've covered quite a bit of ground and we hope that you've already been able to put some of this knowledge to use.

An accepted instructional technique is to (1) tell the student what you're going to tell him; (2) tell him; (3) then tell him what you've told him. In Lesson One, your were told all about the course. The format, supplement, and military standards were introduced. In Lessons 2 through 19, you were given the information necessary to understand man's capabilities and limitations. That leaves Lesson 20 to recap what has come before.

This lesson will serve multiple purposes. First, it will give you a chance to review the rather large amount of information to which you've been exposed. Secondly, it will tie together some loose ends. Thirdly, it will reinforce what you have learned up to now. Fourthly, it will expose personal information gaps which you might have experienced. Then you will be ready for more!

Lesson 1 served as an introduction to the course and emphasized its main objective. Do you recall what that was? Your main objective in taking this course in Human Factors Engineering was:

(1) To obtain the Human Factors Engineering background necessary to do your job well. Turn to Page 38.
(2) To understand man's capabilities and limitations. Turn to Page 34.
(3) To understand the military procedures involved in a Human Factors Program. Turn to Page 47.

- -

From Page 63

(1) Close, but research has shown that short rest periods are more effective in maintaining overall performance levels than one long one. Return to Page 63.

- -

LESSON 18: ATMOSPHERIC EFFECTS, OR I CAN'T BREATHE

Hello, welcome back to your Human Factors Engineering Course. This is Lesson 18, which deals with various atmospheric gases and their effects on human beings. We thought you'd like to get wind of what I. M. Eager and his perfect helicopter were up to.

Actually, at the end of Lesson 17, the perfect helicopter wasn't up to anything. Eager had fixed all the defects in its equipment and the perfect chopper had performed superbly on its sustained flight to the frozen North. When he ran into the igloo BOQ to escape the freezing weather, Eager had detected a defective cannister of tear gas. Correctly perceiving the immediacy of the situation, Eager sounded the gas-mask alarm.

No injuries had occurred as a result of the tear gas, the gas masks had prevented the noxious fumes from causing any serious harm. However, the men wanted an explanation from Eager as to why he was there in the first place. Hopping up and down in his excitement and pride, Eager began to relate the capabilities of his perfect helicopter...he also conveniently managed to forget all the disastrous things which had occurred during its development.

So, now you probably want to know what this lesson will cover. Well, we will begin with a brief discussion of the atmosphere around us. Then, we will deal with some of the various gases that are contained in the atmosphere and their effects on people. In addition to atmosphere gases, there are also a variety of air and chemical pollutants that could be used in a warfare situation. This lesson will deal with the protection methods recommended in MIL-HDBK-759 for these various chemical warfare agents, and you will learn about radiation and how to protect individuals against overexposure. So, let's begin.

The gaseous composition of the environment in which we live is critical to our life processes. In the normal earth environment, the atmosphere consists of oxygen and nitrogen. Oxygen makes up about 20 percent of the atmosphere and nitrogen provides about 75 percent; of the remaining mixture, carbon dioxide is the largest contributing gas.

The earth's atmosphere can also be described in terms of its pressure and density. At sea level, the earth's atmosphere has a pressure of 14.71 pounds per square inch. At higher altitudes, air pressure decreases and the atmosphere is less dense than at sea level. These factors, pressure and density, interact in their effect upon human beings. In your supplement on Page 44, there is a chart which presents the various effects that decreasing pressure and high altitude have upon you.

(Go on to the next page)

From Page 77

To get an idea of what the atmospheric pressure means in terms of performance, look at your supplemental chart. If you were suddenly transported to the top of a very high mountain, you would expect your reaction time to increase. You would also experience a greater degree of fatigue when performing an ordinary task on the mountain than you would feel performing the same task at sea level. As the air pressure is decreased, less oxygen is available for absorption by the blood system. This may lead to a condition of too little oxygen in the body. This condition is called hypoxia. Depending upon the severity of the hypoxic condition, its effects can range from subtle ones (which are detectable only by sophisticated examinations) to severe effects, such as convulsions, paralysis, and unconsciousness.

Now, during high altitude flights the body might receive too little oxygen and hypoxia might occur. How do you think this is usually avoided?

(1) By using oxygen masks and chemical blood thinners. Turn to Page 42.
(2) By using oxygen masks and pressurized cabins. Turn to Page 11.
(3) By using oxygen masks and making only low altitude flights. Turn to Page 18.
(4) By using pressurized cabins. Turn to Page 2.

From Page 89

(3) A PTS would occur long before the bones of the middle ear would shatter as a result of noise. Return to Page 89.

From Page 74

(1) Very good, you're exactly right. Design and protective equipment are the ways to combat toxic atmospheric conditions.

The final topic considered in the first half of this course was noise. Noise was defined as any auditory stimulus that had no real information relative to task completion. As you saw, noise could enhance or detract from human performance. In general, intense intermittant noise detracts from performance. Therefore, as a human factors engineer, you avoid systems which produce this distraction. An important factor introduced was that of TTS. Do you remember what this was? Which of the following statements is a definition of TTS?

(1) A measure of noise. Turn to Page 18.
(2) A permanent loss of hearing due to prolonged exposure to intense noise. Turn to Page 94.
(3) A temporary loss of sensitivity as a result of continued exposure to high sound intensity. Turn to Page 45.

From Page 62

(2) The computer center will need to be protected, but not by this method. The best way to protect this station would be by the collective protection-overpressure method. Return to Page 62.

From Page 64

(1) This was a pretty good guess. All of these characteristics enhance performance, but one of these answers provides an additional enhancing variable. Return to Page 64.

- -

From Page 54

(4) Correct, gradual acclimatization will prepare the individual for tolerating more severe temperatures.

Here are some additional ways to help make an extreme environment more tolerable.

(1) Select personnel who can tolerate the condition. You may try out the individual for a few days. We know that this probably isn't feasible very often, but when it is, it is a good action to follow.

(2) Establish work-rest schedules that will allow recovery from any adverse physiological effects the environment may create.

(3) Additional CLO units will, when they can be used, add to the length of time the individual can be exposed to severe cold.

Now, see if you need to review this section to answer the following question: Performance decrements due to extreme cold are most often associated with which body part?

(1) Hands. Turn to Page 21.
(2) Trunk. Turn to Page 3.
(3) Head. Turn to Page 83.

- -

From Page 55

(2) You're right, but there is a better answer. Return to Page 55.

- -

From Page 71

(2) Exactly right. And as you recall, these data are presented in MIL-STD-1472 and MIL-HDBK-759.

With these data you were just about ready to proceed to designing equipment or a system, but you needed a little more guidance. Therefore, you were presented two principles related to anthropometric design. Think for a moment. What were they?

(1) Designing for the extreme individual and designing for the population's statistical mean. Turn to Page 31.
(2) Designing for the 50th percentile and designing for the adjustable range. Turn to Page 17.
(3) Designing for the extreme individual and designing for an adjustable range. Turn to Page 22.

From Page 52

(2) This is not entirely true. Frequencies in the "mid-range" require smaller increases in intensity to overcome the masker than do low or high frequencies. Return to Page 52.

From Page 54

(2) Increasing starch in a diet won't help people tolerate an adverse environment. Return to Page 54.

From Page 35

(4) Very good. You're absolutely correct. All of these concepts come into play in the design of a man-machine system.

Well, try as he might, Eager's buddy was unsuccessful in his attempt to convince Eager. So, he decided to show him some practical examples of how HFE has been an integral part of system success, as well as some times when HFE was ignored, and shouldn't have been. In fact, three main reasons were given for poor system design.

(1) The capabilities of man were not clearly differentiated from those of the machine.
(2) Human performance capabilities, skill limitations, and response tendencies were not adequately considered in the design.
(3) There was little standardization of controls.

In addition, studies by Paul Fitts on the operation and use of aircraft were reviewed. The point made from these studies was that an enormous number of pilot errors occurred. CPT. Smart told Eager about this to make one point. What was that point?

(1) Equipment rarely malfunctions; the problem usually rests with the human operator. Turn to Page 94.
(2) A major cause of these pilot errors was inadequate human factors input into the design of the man-machine interface. Turn to Page 36.
(3) Aircraft design technology has been progressing at an excessively fast pace. Turn to Page 87.

From Page 10

(3) You are incorrect; all the necessary information for finding the lower limits of alarm detectability has been provided. Return to Page 10.

From Page 59

(1) Your answer is incorrect. Think about what has been said thus far. Return to Page 59.

From Page 35

(3) This is true, but aren't the other statements also true? Return to Page 35.

From Page 24

(1) Both of these factors affect performance, but is that all that is important to the human factors engineer? Return to Page 24.

From Page 80

(3) Sorry, but this answer is wrong. Return to Page 80.

From Page 36

(3) Very good. The general statements that man is flexible, but may be inconsistent, and that machines are highly reliable, but rigid, really sum it up in a nutshell.

Lesson 4 went into greater detail on man's information processing capabilities and limitations. One key point of this lesson was that man does not have the capability to deal with everything presented to him in the environment. This is important for you, as a designer and a human factors engineer, to know. Why?

(1) You must be aware that man is rather limited in what he can do, and thus, equipment must be designed so as to relieve man of much of this burden. Turn to Page 5.
(2) Because you must design a system in such a way that the man is able to (A) receive the information required, (B) process it accurately, and (C) react to it in a suitable fashion. Turn to Page 27.
(3) It's important because in conducting a systems failure analysis, you need to be able to list the information which man could not process and evaluate in terms of importance to mission success. Turn to Page 17.

From Page 24

(3) If clothing requirements were the sole concern of the HF specialist, he/she would be neglecting some important environment concerns. Return to Page 24.

From Page 22

(1) Very good. An activity's importance to mission accomplishment, the frequency of use of a given component, the function of that component, as well as the patterns of the operation of the components are all key principles for work space design.

These principles will help you decide what the best design might be only if you have data on which to base your decisions. Lesson 7 also presented methods for measuring and gathering these data on human activities or operations. Methods such as film analysis, direct observation, questionnaires, and interviews are all valid methods for gathering data. The operational relationships which are evident from this analysis are usually expressed in terms of:

(1) Link values or indexes. Turn to Page 96.
(2) Operational requirement values. Turn to Page 65.
(3) Proximity scales. Turn to Page 37.

From Page 62

(1) Infantry troop would not be very effective if they were all hooded up to a central filter. This is a situation which required individual protective gear. Return to Page 62.

- -

From Page 52

(1) Your answer is incorrect. The highest shown frequencies require the largest dB increase. Return to Page 52.

- -

From Page 35

(1) This is true, but aren't the other statements also true? Return to Page 35.

- -

From Page 74

(2) Chances are that some fatalities would still result if proper ventilation was the HF specialist's only concern. Return to Page 74.

- -

From Page 6

(6) This answer is an example of a physical task, but those tasks that require the greatest amount of exertion are the one most affected by heat stress. Return to Page 6.

- -

From Page 10

(4) You are incorrect; a correct answer has been provided as one of the possible choices. Return to Page 10.

From Page 82

(3) Aircraft design technology was indeed proceeding quite rapidly, but the problem was that HFE input wasn't considered in the process. Return to Page 82.

From Page 27

(1) Close, but there was no mention of personality. Return to Page 27.

From Page 74

(3) While protective gear is an important aspect of designing for safety from atmospheric effects, there are other factors that must be taken into account by the HF specialist. Return to Page 74.

From Page 5

(1) Your answer is incorrect. Three other variables are presented which improve performance more. Return to Page 5.

From Page 48

(2) You are not entirely correct. Primarily, a masker will mask a tone at about the same frequency, but it has been shown that high frequency tones can, in fact, mask low frequency tone. Return to Page 48.

From Page 32

(2) You're quite right. TTS can affect performance from a physiological standpoint; in fact, the noise that causes the TTS can be an annoyance as well. However, when speaking specifically about annoyance, one is referring to noise detrimentally affecting performance in psychological terms.

TTS can affect man's ability to perform adequately tasks that require maximum hearing sensitivity. In fact, the ability to maintain hearing acuity can have an important role in life-and-death situations. For example, the ability to perceive auditory warning signals, or the need in the past for astronauts to be able to receive speech signals immediately after blast-off, influences life-and-death decisions. Another example, and one that is possibly closer to home, would be the effect that a wailing siren might have on the ability of firemen to communicate effectively once they've reached their destination. From what we've said so far about TTS, you can imagine that a ride of this sort could easily result in a TTS. These types of after effects must be taken into account when designing equipment and machinery of any sort.

Temporary loss of sensitivity is not the only result of continued exposure to high sound intensity, however. TTS occurs with exposure to noise over a certain period of time. However, with additional exposures, the amount of recovery from these noise effects gradually becomes less and less, until it results in some permanent hearing loss (permanent threshold shift OPTS). Now, thinking back over what has been said about TTS, why would you think this permanent hearing loss takes place?

(1) All of these problems result from prolonged exposure to noise. Turn to Page 74.
(2) Because the constant noise causes a severe irritation of inner ear tissue, hearing sensitivity is permanently reduced. Turn to Page 38.
(3) Prolonged exposure to noise causes the bones of the middle ear to shatter, and thus results in permanent hearing loss. Turn to Page 78.
(4) Like TTS, a person's minimum audible threshold is raised, but does not return to its original level of sensitivity. Turn to Page 25.

From Page 55

(4) Good show, you're absolutely right. All of these statements are true.

So, as you can see, there are a number of important factors that affect watch-keeping behavior. We hope you'll keep in mind these variables that affect vigilance in your future interactions in the area of Human Factors Engineering. Before we sign off we should check with I. M. Eager to update our "state of the helicopter" information.

If you'll remember, when you last visited Eager, he had undertaken a rather long test flight to Northern Alaska. In route, Eager began to realize the importance of watch-keeping behavior and some of the relationships between variables that we've been discussing. Luckily for Eager (and the continuation of this story line), he was able to "weather the storm." However, as his helicopter began to reach more northern (and colder) climates, Eager also began to realize that he had *failed to take* numerous environmental conditions, such as temperature, into account.

Okay, you've now finished Lesson 16. In the next lesson, 'Baby It's Cold Outside,' you'll be exposed to the elements (so to speak). This lession will deal with the effects on performance of extreme temperatures. You'll also need to become familiar with the supplement pertaining to this lesson which includes several figures and military standards on this topic. Turn to Page 67 to begin Lesson 17.

From Page 26

(3) Well done, you catch on quickly. By finding the point of intersection between four hours and the diagonal line representing frequency limits above 300 Hz, you were able to cross over to the left-hand margin and locate 100 dB.

So, you can see by looking at these DRC's one can get an idea of what limits he must impose for safety's sake. There are a number of different types of DRC's all of which convey the same type of information about tolerable noise limits. Some DRC's give exposure limits for pure tones, others for continuous noise, and for example, Figure 19.7 gives a DRC for intermittent noise.

Another method of achieving acceptable noise levels is through the use of mechanical hearing protectors, which come in a variety of shapes and sizes. For our purposes, these devices can be grouped into three basic categories--earplugs, earmuffs, and helmets. Earplugs can be made of rubber or plastic, or even disposables, such as waxed cotton, and dry cotton, when it is desired to lower the noise level without reducing speech intelligibility.

Earmuffs, on the other hand, attenuate (reduce) sound as well as, or better than, earplugs at high frequencies. However, they are slightly poorer than plugs for frequencies below 1,000 Hz. A major drawback for use of earmuffs is due to their bulk and relative expense. In cases where very intense noise levels exist, it may be desirable to wear both earmuffs and earplugs.

Finally, helmets can be used more effectively than the other devices when the sound pressure levels (SPL) are intense enough to cause boneconducted sound transmission (that is, sound waves which are transmitted to the inner ear via the bones of the skull). The effectiveness of a helmet results because it covers a much greater portion of the head. Thus, while the maximum alternative which can be provided by an earplug or earmuff is about 35 dB at 250 Hz (it is greater at higher frequencies), helmets can effectively increase this level of attenuation by about 10 dB.

(Go on to the next page)

From Page 91

We want you to realize that the first desire of human factors engineers is to reduce the noise level to a tolerable intensity. Why, then, would one even need to rely on hearing protection devices? Wouldn't it be advisable to either reduce the noise level to an acceptable level, or refuse to let anyone near that noise source?

(1) No, regardless of the danger, sometimes it's necessary to continue to work in excessively noise environments without the aid of hearing devices. Turn to Page 15.
(2) Yes, that would be best, but situations arise where it is neither economically nor practically feasible to remove people from the work setting to a position some distance from the source. Turn to Page 95.
(3) Neither of these answers is correct. Turn to Page 26.
(4) Both of these answers are correct. Turn to Page 37.

From Page 52

(4) Your answer is incorrect. The lower and higher frequencies require greater dB increased than do the mid-range frequencies. Return to Page 52.

From Page 5

(4) Your answer is incorrect. Return to Page 5.

AD-A132 559 HUMAN FACTORS ENGINEERING A SELF-PACED TEXT LESSONS 16-20(U) HUMAN ENGINEERING LAB ABERDEEN PROVING GROUND MD R BROGAN ET AL. AUG 81 2/2

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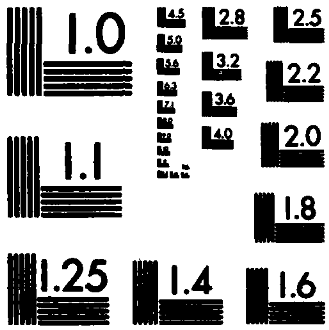

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

From Page 36

(2) Look a little more closely. Some of the ideas presented are not accurate. Return to Page 36.

From Page 74

(4) While it's important to design so as to reduce chances of exposure to toxic substances, the possibility of exposure must still be accounted for and properly dealt with by the HF specialist. Return to Page 74.

From Page 44

(4) You're partially correct in that a noise range of 100-112 dB detrimentally affects vigilance. However, this answer is not the best possible answer, because the temperature range does not detrimentally affect performance. Return to Page 44.

From Page 7

(2) While a general overall performance decrement is evident over time, studies have noted the fact that a slight recovery or 'end-spurt' occurs near the end of the watch period. Return to Page 7.

From Page 64

(2) Long watches are not conducive to watch-keeping. Return to Page 64.

From Page 82

(1) Not really. While these studies did show a geat deal of human error, nowhere do they espouse the infallibility of machines. Return to page 82.

From Page 79

(2) No, that is referred to as PTS, permanent threshold shift. Return to Page 79.

From Page 92

(2) Well done. You're absolutely right. Often there are situations where man cannot be removed from the noise source. An example is the exposure of astronauts and the huge blast that results from the large boosters required to propel spacecrafts into orbit.

Before you end another lession, let's return to our little saga of I. M. Eager and hear what's being said...actually, if you'll remember, Eager was having trouble hearing what was being said due to the 21-gun salute. Well, fortunately for our hero, it was only a temporary hearing loss, and soon he was aware of the high praise being bestowed on him by his colleagues. It was, indeed, sweet music in his ears--unfortunately, what he actually heard was the clamour of the alarm, awakening him from this amazing dream. You do remember that this was all a dream? Fortunately for Eager, it was an extremely helpful dream because it made him aware of the importance of Human Factors Engineering and made him start thinking about his need to begin learning the 'ins-and-outs' of this extremely interesting and important field.

Turn to Page 76 to begin Lesson 20.

From Page 38

(3) While this statement is true, it doesn't really deal with the difficulties of Human Factors Engineering and Scientific Research and Application. Return to Page 38.

From Page 85

(1) That's correct. These links are of three main types--movement links, which show the sequential movement of people from one compartment to another; control links, which examine the activities of man controlling machines; and communication links, which describe the relationships of the communication network in a space.

After concluding this general overview of work space design, you then focused on some details of euqipment design. Lessons 8 and 9 dealt with man's visual capabilities and performance requirements related to vision. You were introduced to the dual aspects of vision (rods and cones), as well as several key processes involved in the visual sense. One of these which is crucial to operators involves the difficulty one experiences when going from a lighted room to a darkened operating space. What is the process called that our eyes go through in adjusting to this kind of change in illumination?

(1) Light sensitivity. Turn to Page 28.
(2) Dark adaptation. Turn to Page 97.
(3) "Night operator" syndrome. Turn to Page 31.

From Page 32

(1) While it might be true that intensity differences may appear to separate the two concepts, this is not necessarily so. Low or high intensities may be associated with either concept. Return to Page 32.

From Page 96

(2) Exactly right. This process is one which a designer must take into account when designing operational systems.

Many other factors were reviewed in these lessons. The problems produced by glare were examined, as was the need for adequate panel lighting. The advantages of the two basic methods of panel lighting (flood and integral) were reviewed together with their inadequacies. Integral (built-in) lighting, for example, helps eliminate shadows, but does not aid in illuminating labels above gauges. Flood lighting may provide better overall lighting, but it is likely to cause shadows and it is often bulky.

In examining the theory of display design, it was noted that there are two basic types of display; namely, quantitative and qualitative displays. Various qualitative and quantitative scales were reviewed, as were their respective advantages and disadvantages. Think back to that presentation. You were given the pros and cons of the various types of visual displays, of work space design, and of men and machines, but you were never really given hard-and-fast rules. This is because the human factors engineer must look at the total man-machine system before deciding on the best fit of its parts.

So it is with displays. The choice as to which type of display (i.e. quantitative or qualitative, static or dynamic) is best rests on what its use will be, who will be using it, its criticality in the system, and other factors relevant to the man-machine interaction.

Let's say that you were required to design a display which would present constantly changing information and which would allow precise reading and interpretation of the presented information. Which of the following types of displays would you use?

(1) A dynamic display such as a moving scale with a fixed counter. Turn to Page 34.
(2) A static display such as a counter. Turn to Page 27.
(3) A dynamic display such as a counter. Turn to Page 29.

From Page 32

(3) Definite differences exist between the two concepts in terms of how the individual is affected by the noise. Return to Page 32.

From Page 36

(1) Think a little more. When was the last time you saw a machine 'react' creatively to an emergency or demonstrate flexibility of action? Return to Page 36.

From Page 45.

(2) No? Well, take a 5 minute break and answer this question again. On second thought, so we don't waste any time, just change your choice of answers. Return to page 45.

From Page 47

(4) Very good, this is exactly right. By increasing the temperature 15 degrees, you've now made the range between 75° and 80°F, and surprisingly enough, this is within the comfort range.

So, you've come to the second section of this lesson. Before going on, let us direct you to the appropriate MIL-STD to use in the future. To determine ET, given temperature, humidity, and air speed, see figure titled "Effective Temperature" in MIL-STD-1472. The same MIL-STD in a figure titled "Summer and Winter Comfort Zones and Thermal Tolerance for Inhibited Compartments" presents the temperature levels that an individual, who is doing light manual work, can tolerate for various durations. You will now be exposed (pun intended) to some information concerning reactions to cold environments. According to the latter figure, what is the highest level of vapor pressure that is acceptable for a summer comfort zone?

(1) 30 MM HG. Turn to Page 18.
(2) 20 MM HG. Turn to Page 53.
(3) 6 MM HG. Turn to Page 6.
(4) All of these are within acceptable limits. Turn to Page 20.

From Page 5

(2) This is not the best possible answer. Please reconsider each variable we discussed and compare answers to find the one where all three maximally aid watch-keeping behavior. Return to Page 5.

From Page 59

(2) A number of short rest intervals is better than one long rest interval. You're absolutely right.

Research has demonstrated that a number of short rest intervals is more effective in maintaining overall performance levels. This effect may, in fact, be due to interruption of the monotony of the task, rather than the actual physical recupertion that may occur during the rest period.

A final procedural variable of vigilance of importance to study is the duration of the watch period. Before we get into a discussion of this topic, we think you've come far enough in this course to reason out the answer to the following question, especially in light of what we touched on thus far with procedural variables. So, how can performance be improved in terms of duration of the watch period?

(1) By increasing the length of the rest interval and increasing the length of the watch period. Turn to Page 47.
(2) By making sure the watch stander is in excellent physical condition. Turn to Page 16.
(3) By allowing the person to bring other work to the watch station in order to break the monotony. Turn to Page 35.
(4) None of these answers are correct. Turn to Page 64.

From Page 7

(3) You're wrong here. It might be good to go back and reread this section before continuing on. Return to Page 7.

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